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PERFORMANCE AND ATTITUDE TOWARDS PHYSICAL ACTIVITY AMONG VIRTUAL WALKATHON PARTICIPANTS IN THE POST-PANDEMIC PERIOD

Warlen Ruzgal ALEJANDRIA [1*]

ABSTRACT. *Introduction*: The "new normal" has defined societal functioning in recent years and remains a crucial consideration as communities continue their path toward recovery and adaptation. Strategic disruption-proof wellness initiatives were explored to strengthen readiness of institutions. *Objective:* This study was conducted to find out the actual performance and attitude towards physical activity among the participants of a virtual walkathon in the post-pandemic period. *Material and Methods*: This one-group pretest–posttest quasi-experimental study involved 211 college students who had completed the requirements for inclusion. The participants had to have an internet connection and a pedometer app installed on their phones and were required to complete the Attitude Towards Physical Activity questionnaire before and after the activity. Frequency, percentage, mean, and standard deviation were used in analyzing the data. Tests such as the Wilcoxon Signed Ranks, Kruskal-Wallis, Mann-Whitney and the Spearman's Rho were utilized in comparing and finding the difference and relationships in the variables. *Discussion:* Results revealed a significant difference in all the sub-domains of the attitude towards physical activity among the participants when responses were compared before and after the intervention. Likewise, it shows that age have significantly affected the actual performance of the participants. There is an inverse relationship between the actual performance and the attitude towards physical activity particularly in the physical activity as a social experience. *Conclusions:* The findings revealed that active participation in innovative activities can foster desirable attitudes toward physical activity, thereby promoting desirable health practices and supporting the institutionalization of wellness programs.

Keywords: attitude; performance; wellness; physical activity; walkathon

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INTRODUCTION

The “new normal” has characterized global life for several years and remains a crucial consideration as societies continue to recover from the unprecedented disruptions caused by the pandemic (Tria, 2020) (Ma et al., 2023). Various sectors implemented diverse strategies to mitigate its adverse impacts and sustain essential functions despite widespread interruptions (Abideen et al., 2020) (Ebrahim et al., 2020). Strict health and safety protocols such as physical distancing, frequent handwashing, and the use of face masks or face shields were enforced during its height to prevent further transmission (World Health Organization, 2020).

Preventive health protocols have led to a marked reduction in physical activity and exercise routines worldwide (Ainsworth & Li, 2020) (Bichescu et al., 2021). Many public spaces that foster social interaction were closed, while educational institutions and workplaces were either suspended or transitioned to alternative operational schemes to sustain their functions (Assefa, 2023). This situation underscored the need for recalibrating and enhancing wellness through accessible physical activity (PA) opportunities (Amini et al., 2021) (Sallis et al., 2020a). In response, (Sallis et al., 2020b) emphasized the importance of developing research and initiatives that address several key areas: (a) promoting PA as a mitigation strategy to lessen pandemic impacts; (b) refining PA measurement tools relevant to crisis contexts; (c) examining behavioral changes in PA; (d) reducing disparities in PA engagement; (e) designing interventions that consider social, cultural, and environmental influences; and (f) translating findings into practical applications and policies for current and future public health challenges.

Innovative initiatives promoting physical activity emerged during the global health crisis to sustain wellness and engagement despite restrictions on movement (Reyes et al., 2021) (Ritmak et al., 2023) (Markovič et al., 2021). Experts and union organizations have suggested physical activity at home in this regard (Aguirre-Loaiza et al., 2021). In the United Arab Emirates, for instance, several virtual fitness events were organized, including the Virtual Marathon in Dubai, the Stay at Home Virtual Run in Abu Dhabi, the ADNOC Abu Dhabi Virtual Marathon, the Stay at Home FBMA Ladies Run, and the RAK Medical and Health Sciences University (Stay Home, Be Fit) Virtual Mini Marathon (Elmagd, 2020). In Romania, the study of (Iconaru et al., (2023) emphasized the promotion of guided interventions for recovery and healthier living as part of the post pandemic landscape. These creative undertakings exemplify adaptive strategies that are likely to shape the evolving landscape of wellness promotion and sports participation in the post-pandemic era (Gould et al., 2020).

Healthier living while moving forward requires a sound mindset that supports continuous growth and the fulfillment of individual and communal goals within society (Fariss et al., 2023). Initiatives aimed at shaping individual behavior toward sustainable living, improved health, and acceptance of innovative practices have largely relied on strategies centered on information dissemination and attitude transformation. Research suggests that changes in attitudes can significantly influence behavioral outcomes (Verplanken & Orbell, 2022). Moreover, aligning physical education with individual needs and interests may further enhance positive attitudes, serving as an additional motivating factor. A favorable attitude toward physical education has also been identified as a potential predictor of one's inclination to engage in physical activity (Rullestad et al., 2021). Despite the fact that consciously developed intentions do not always result in actual behavior, the implementation of strategies that strengthen positive implicit attitudes toward exercise and reduce negative implicit attitudes toward exercise may greatly contribute to the promotion of increased physical activity participation (Hagger et al., 2020).

Current digital technologies can be effectively utilized for training, performance monitoring, and enhancing athletes' overall development and exercise habits across diverse populations (Specker Sullivan & Reiner, 2021). For instance, pedometer applications are among the most widely used tools for tracking physical activity, particularly walking (McCormack et al., 2022). The integration of such technologies into daily routines or environments has the potential to influence individuals' level of effort and sustain positive behavioral changes over time (Robinson et al., 2020) (Goodyear et al., 2023). The innovative electronic educational tool represents a novel academic methodology for physical activity and a health promotion strategy that empowers students, advocates for healthy lifestyles, and facilitates an improved quality of life (Vankova & Videnova, 2020). The utilization of these technologies in physical education demonstrates the capacity to holistically address the objectives of physical education and foster the human attributes (Corrales & García-Fernández, 2023).

To explore the effectiveness of integrating technology and innovative approaches in promoting physical activity, Aklan State University implemented a virtual walkathon aimed at fostering proactiveness and resilience in light of lessons learned from the recent global health crisis. The data collected from participants particularly regarding the effects of the intervention and the degree of correlation among key variables will serve as a valuable basis for enhancing policy frameworks that support a more resilient and health-conscious community.

MATERIAL AND METHODS

Participants

The study was conducted among the students of the five campuses of Aklan State University. From the 5 campuses of ASU, there were 543 volunteer college students included in the population for the study. Out of the population, 211 had successfully finished the intervention and completed the required tasks and were counted-in as the samples of the study. The approval of the University Ethics Committee was secured as well as informed consent was obtained from all the participants. Similarly, this study complied with the Declaration of Helsinki's rules (World Medical Association, 2013).

Procedure and Materials

The one group pretest-posttest quasi-experimental research design was used. Each participant was instructed to download the Pedometer app (free via app stores) and be installed in their cell phones. Participants have accomplished a registration form and the Attitude Towards Physical Activity questionnaire through Google Forms. An online page was provided for registered participants for the event instructions. Although there was leniency in social policies during the conduct of the intervention, participants were advised to still practice safety health protocols. Such as to perform the activity alone as part of the social distancing preferably inside the house, own lawn, working place, or in the local vicinity. Proper warm-up and cool down exercises were instructed before and after of each walking sessions.

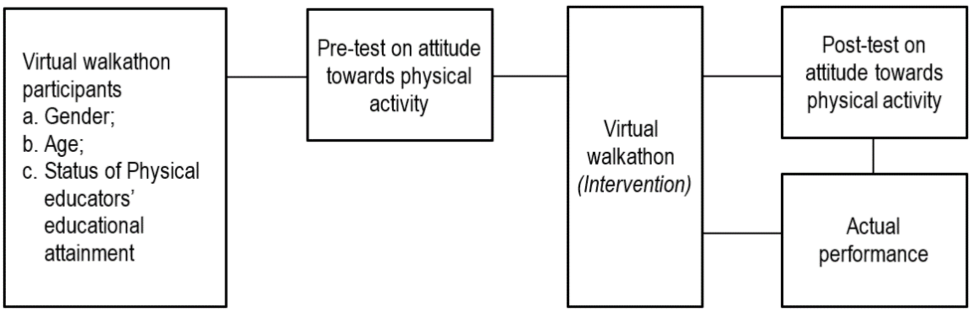


Fig. 1. Conceptual Framework of the Study

The activity had the duration of 3 days which included the virtual walk-off ceremony and the closing and awarding program. Registration period was done prior to the three-day activities. The schedule of activities is as follows:

Time Frame	Activity
Day Zero	· Registration · Giving of ATPA Questionnaire (pre-test) · Guidelines posting at the social media page
Day 1	· Start of activity · Sending/receiving of data for monitoring · Posting of reminders.
Day 2	· Continuation of activity · Sending/receiving of data for monitoring · Posting of reminders.
Day 3	· Continuation of activity · Sending/receiving of data for monitoring/analysis · Posting of reminders. · Administering of ATPA Questionnaire (pre-test) · Closing
Proceeding Weeks	· Data Analysis

Fig. 2. Schedule of Activities

Data analysis

There were intended team organized to each campus for receiving, encoding and monitoring of the progress of the participants. SPSS Statistics version 21 was used for the statistical analysis of the data collected. Descriptive statistics such as frequency, percentage, mean, and standard deviation were used and Attitude Towards Physical Activity was described as follows:

Scale	Description
4.50 – 5.00	High Inclination
3.50 – 4.49	Moderate Inclination
2.50 – 3.49	Neutral
1.50 – 2.49	Moderate Inclination
0.00 – 1.49	Low Inclination

Inferential Tests such as the Wilcoxon Signed Ranks, Kruskal-Wallis, Mann-Whitney and the Spearman's Rho were used in comparing and finding the difference and as well as relationships in the variables. The used of non-parametric tests in the analysis of the data was used due to the non-normality of the data using the Shapiro-Wilk test (Gosselin, 2024).

Table 1. The results of Shapiro-Wilk test

	Shapiro-Wilk		
	Statistic	**df**	**p-value**
Total Steps	.713	211	.000
Q1pre	.728	211	.000
Q2pre	.654	211	.000
Q3pre	.705	211	.000
Q4pre	.827	211	.000
Q5pre	.785	211	.000
Q6pre	.724	211	.000
Q1post	.428	211	.000
Q2post	.320	211	.000
Q3post	.533	211	.000
Q4post	.686	211	.000
Q5post	.604	211	.000
Q6post	.461	211	.000

p-value < 0.05 indicate non-normal data

RESULTS

In Table 2, the participants were presented according to gender, age, and status of physical educators' educational attainment. There were lesser male participants 53 (58%) compared to females 158 (74.9%). In terms of age, majority of the participants were 17-19 years old at 113 (53.6%) while the least were in the age of 26-above with 10 or 4.7%.

Table 2. Profile of Virtual Walkathon Participants in Terms of Gender, Age and Status of Educational Attainment of Physical Educators

	Frequency (n = 211)	**Percentage**
Gender		
Male	53	25.1
Female	158	74.9
Age		
17-19	113	53.6
20-22	85	40.3
23-25	3	1.4
26-above	10	4.7
Status of Physical Educators		
Majority are masters	134	63.5
Majority are PhD/EdD	77	36.5

In table 3, the mean for the ATPA Sub-domains 1, 2, 3, 4, 5, and 6 during the pre-test were 4.27, 4.56, 4.38, 4.04, 4.13, and 4.37 respectively. For the post-test, ATPA Sub-domains 1, 2, 3, 4, 5, and 6 have means 4.80, 4.81, 4.38, 4.46, 4.56, and 4.72, respectively. For the sub-domains 1, 5, and 6 such as the physical activity as a social experience, pursuit of vertigo and as an ascetic experience, there were changes from moderate inclination to high inclination (4.27 to 4.80; 4.13 to 4.56; and 4.37 to 4.72). It indicates that there is change in attitude or increased their inclination in the sub-domains indicated.

Table 3. Participants' Attitude Towards Physical Activity (ATPA) Before and After the Virtual Walkathon

ATPA Sub-domains	Pre-test Mean	SD	Decription	Posttest Mean	SD	Decription
1. Physical activity as a Social Experience	4.27	0.63	Moderate Inclination	4.80	0.51	High Inclination
2. Physical activity for health and fitness	4.56	0.59	High Inclination	4.81	0.64	High Inclination
3. Physical activity as catharsis	4.38	0.60	Moderate Inclination	4.38	1.24	Moderate Inclination
4. Physical activity as an aesthetic experience	4.04	0.76	Moderate Inclination	4.46	0.76	Moderate Inclination
5. Physical activity as the pursuit of vertigo	4.13	0.70	Moderate Inclination	4.56	0.75	High Inclination
6. Physical activity as an ascetic experience	4.37	0.62	Moderate Inclination	4.72	0.64	High Inclination

In table 4, the ATPA sub-domains as based on the responses of the participants, it shows that in all of the parameters there were significant differences before and after the virtual walkathon. Physical activity as a social experience, for health and fitness, as catharsis, as an aesthetic experience, as the pursuit of vertigo, and as an ascetic experience has the p-value of 0.000, 0.000, 0.035, 0.000, 0.000, and 0.000 respectively. This suggests that there is significant change in attitude or significantly increased their inclination in the sub-domains indicated. The figure shows the attitude of the participants towards physical activity.

Table 4. Difference on the Attitude Towards Physical Activity (ATPA) Before and After the Virtual Walkathon

ATPA Sub-domains	z value	p value	Decision
1. Physical activity as a Social Experience	10.097	0.000	p<0.05, Reject Ho
2. Physical activity for health and fitness	6.356	0.000	p<0.05, Reject Ho
3. Physical activity as catharsis	2.114	0.035	p<0.05, Reject Ho
4. Physical activity as an aesthetic experience	8.058	0.000	p<0.05, Reject Ho
5. Physical activity as the pursuit of vertigo	8.108	0.000	p<0.05, Reject Ho
6. Physical activity as an ascetic experience	7.480	0.000	p<0.05, Reject Ho

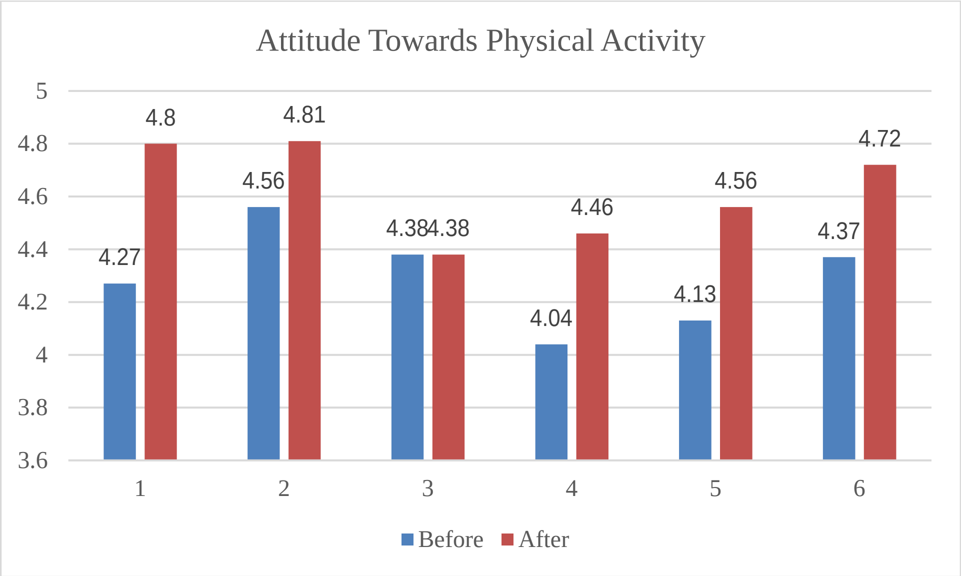


Fig. 3. Comparison of ATPA Before and After the Virtual Walkathon

In table 5, the actual performance of the virtual walkathon participants is presented in terms of gender, age, and status of physical educators' educational attainment. In terms of gender, male participants have higher actual performance ($\bar{x}$=32789.47) compared to female participants ($\bar{x}$=24654.59). As to age, those who belong to age bracket 26-above have the highest average actual walkathon performance ($\bar{x}$=52132.00) while those who aged 17-19 delivered the lowest average actual performance ($\bar{x}$=24784.56). With regard to the status of physical educators, there were more student-participants who were majority of their physical educators are master's degree ($\bar{x}$= 28375.62) while lesser case of having a majority doctorate degree physical educators ($\bar{x}$= 23778.38).

Table 5. Actual Performance of the Virtual Walkathon Participants when Grouped according to Gender, Age, and Status of Educational Attainment of Physical Educators

	Mean	**SD**
Gender		
Male	32789.47	35429.05
Female	24654.59	20986.90
Age		
17-19	24784.56	18673.40
20-22	26260.19	30402.94
23-25	26392.33	11743.99
26-above	52132.00	38260.66
Status of Physical Educators		
Majority are masters	28375.62	29477.93
Majority are PhD/EdD	23778.38	16401.49

Table 6 shows that there is no significant difference in the actual performance of the virtual walkathon participants when grouped according to gender with the z-value of 1.690 and p-value of 0.091. This indicates that gender does not affect significantly to the actual performance of the virtual walkathon participants.

Table 6. Difference of Actual Performance of the Virtual Walkathon Participants when grouped according to Gender

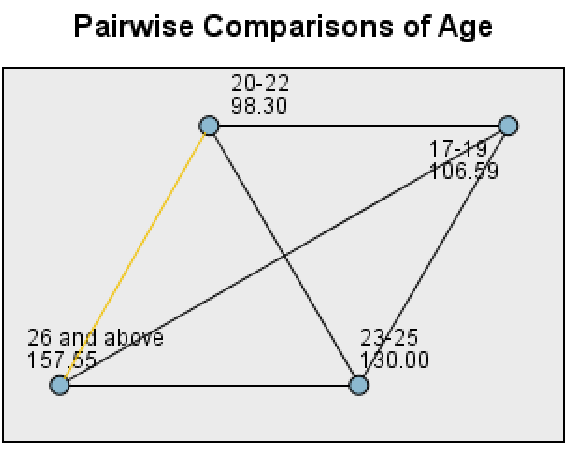
Gender	Mean	Z Value	p value	Decision
Male	32789.47	1.690	0.091	$p>0.05$, Accept H_o
Female	24654.59			

Table 7 reveals that there is a significant difference in the actual performance of the virtual walkathon participants when grouped according to age with a p-value of 0.030. This indicates that age have significantly affected the actual performance of the virtual walkathon participants.

Table 7. Difference of Actual Performance of the Virtual Walkathon Participants when grouped according to Age

Age	Mean	x^2	p value	Decision
17-19	24784.56	3.0	0.030	$p<0.05$, Reject Ho
20-22	26260.19			
23-25	26392.33			
26-above	52132.00			

Furthermore, the pairwise comparison diagram (Graph 1) and Table 7 together indicate that age has a differential effect on the virtual walkathon performance. Specifically, participants aged 26 and above scored or ranked significantly higher compared to those aged 20–22, while other age group comparisons did not show significant differences.



Graph 1. The Graphical Comparison of Effect in Terms of Age

Table 8. The Tabular Comparison of Effect in Terms of Age

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
20-22 - 17-19	8.293	8.766	0.946	0.344	1.000
20-22 - 23-25	-31.7	35.866	-0.884	0.377	1.000
20-22 - 26 and above	-59.25	20.411	-2.903	0.004	0.022
17-19 - 23-25	-23.407	35.715	-0.655	0.512	1.000
17-19 - 26 and above	-50.957	20.143	-2.53	0.011	0.068
23-25 - 26 and above	-27.55	40.191	-0.685	0.493	1.000

Table 9 shows that there is no significant difference in the actual performance of the virtual walkathon participants when grouped according to the status of physical educators' educational attainment with the z-value of 0.164 and p-value of 0.870. This indicates that the status of physical educators' educational attainment does not affect significantly to the actual performance of the virtual walkathon participants.

Table 9. Difference of Actual Performance of the Virtual Walkathon Participants when grouped according to Status of Physical Educators' Educational Attainment.

Status of Physical Educators' Educational Attainment	Mean	z value	p value	Decision
Majority are masters	28375.62	0.164	0.870	$p>0.05$, Accept H_o
Majority are PhD/EdD	23778.38			

Table 10 shows that there is an inverse relationship between the virtual walkathon actual performance and the attitude towards physical activity particularly in the physical activity as a social experience (rho=0.135) with a p-value of 0.050. It would mean that those participants with less inclination to socialize displayed high actual performance while those with strong inclination for socialization through physical activity has low walkathon performance. Other attitude towards physical activity parameters shows no significant difference on performance such as in the physical activity as a social experience, for health and fitness, as catharsis, as an aesthetic experience, as the pursuit of vertigo, and as an ascetic experience that have the p-values of 0.050, 0.266, 0.977, 0.654, and 0.992 respectively.

Table 10. Relationship between the Virtual Walkathon Actual Performance and the Attitude Towards Physical Activity

ATPA Sub-domains	rho	p value	Decision
1. Physical activity as a Social Experience	0.135	0.050	$p<0.05$, Reject Ho
2. Physical activity for health and fitness	0.077	0.266	$p>0.05$, Accept H_o
3. Physical activity as catharsis	0.002	0.977	$p>0.05$, Accept H_o
4. Physical activity as an aesthetic experience	0.031	0.654	$p>0.05$, Accept H_o
5. Physical activity as the pursuit of vertigo	0.001	0.992	$p>0.05$, Accept H_o
6. Physical activity as an ascetic experience	0.018	0.797	$p>0.05$, Accept H_o

DISCUSSION

The results show a noticeable increase in the mean scores of several ATPA sub-domains. This indicates a positive change in participants' attitudes toward physical activity, suggesting that the virtual walkathon effectively enhanced their motivation and engagement in these areas. These findings align with earlier studies such as of Gould et al. (2020), emphasizing that interactive and socially engaging physical activity initiatives can foster more favorable attitudes and sustained participation, thereby supporting the role of innovative and technology-based interventions in promoting active lifestyles. There were statistically significant differences across all ATPA sub-domains before and after the virtual walkathon, indicating that participants' attitudes toward physical activity improved notably following the intervention. The significant p-values across domains such as social experience, health and fitness, catharsis, aesthetic experience, pursuit of vertigo, and ascetic experience suggest that the activity fostered a stronger and more positive inclination toward physical engagement. These results are consistent with earlier study of Aguirre-Loaiza et al. (2021) highlighting that experiential and socially oriented physical activity programs can effectively enhance motivation, enjoyment, and commitment to active lifestyles, reinforcing the value of innovative, technology-supported approaches in wellness. Variations in actual walkathon performance were observed across gender, age, and the educational attainment of participants' physical educators. Older participants (ages 26 and above) achieved the highest performance levels, indicating that maturity and established fitness habits may contribute to greater consistency in physical activity as contrasted to the study of ÁCS et al. (2017) where university students show a more positive responses on physical activity than the adult population. Additionally, students mentored primarily by master's degree holders performed better than those guided by educators with doctoral degrees, possibly reflecting a more hands-on or motivational teaching approach signifying that the decisions made by physical education instructors during lessons affect student learning and the attainment of physical literacy objectives by Arseni & Hanțiu (2022). It was revealed that male and female participants demonstrated comparable levels of physical engagement. This finding implies that gender does not play a determining role in the level of participation or performance in technology-mediated physical activities. This emphasized that opportunities for engagement, motivation, and access to activity platforms can minimize gender disparities in physical performance outcomes as contrasted to the study of Olănescu (2021) where male students are more motivated to participate compared to female students. It was indicated that age has a notable influence on participants' physical activity levels. This suggests that older individuals may possess greater endurance, discipline, or motivation to sustain performance in extended physical activities compared to younger participants. The finding supports earlier research highlighting age as a relevant factor in physical activity engagement, where maturity and lifestyle stability often contribute to higher consistency and commitment to exercise routines where the concept of "more active ageing" is of great consideration nowadays (Sabău & Acqui, 2023). It was suggested that the academic qualification level of physical educators did not substantially influence participants' engagement or performance in the activity. This aligns with earlier studies indicating that factors such as personal motivation, accessibility of technology, and individual fitness habits may have a greater impact on physical activity outcomes than the formal educational background of instructors as stated similarly by Robinson et al. (2020). The findings pointed-out an inverse relationship between actual performance in the virtual walkathon and attitude toward physical activity, specifically in the sub-domain of physical activity as a social experience. This suggests that participants who were less socially inclined tended to perform better, possibly due to greater individual focus and intrinsic motivation. In contrast, those who viewed physical activity primarily as a social pursuit showed lower performance levels, potentially reflecting dependence on group interaction for engagement. The absence of significant relationships in other attitude domains such as health and fitness, catharsis, aesthetic experience, pursuit of vertigo, and ascetic experience supports prior research suggesting that social motivation may influence participation style more than overall physical performance outcomes that was pointed also by Hagger et al. (2020).

CONCLUSIONS

The study provides valuable insights into how technology-enhanced physical activity initiatives, such as virtual walkathons, influence participants' attitudes and actual performance across various demographic and psychological factors. Findings revealed that while gender and educators' qualifications did not significantly affect performance, age played a meaningful role, with older participants demonstrating higher levels of engagement. Interestingly, an inverse relationship emerged between social inclination and performance, suggesting that intrinsic motivation may drive greater individual success in virtual fitness contexts. These results advance the understanding of behavioral dynamics in technology-mediated physical activities, emphasizing the potential of virtual platforms for promoting wellness and resilience in post-pandemic settings. Future research may explore personalized digital interventions and long-term behavioral impacts to further strengthen policy frameworks for health and physical education.

AUTHOR CONTRIBUTIONS

The author performed the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest declared.

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PHYSIOTHERAPY THROUGH EXERGAMES – INFLUENCE IN THE DEVELOPMENT OF STATIC BALANCE FOR CHILDREN WITH NEUROMOTOR DISABILITIES

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ABSTRACT. *Objective:* This study investigates the effectiveness of an innovative therapeutic protocol aimed at enhancing static balance of children with neuromotor disabilities. Exergames and proprioceptive neuromuscular facilitation methods are to be combined and applied as a physiotherapeutic technique to improve standard deviations of the center of pressure (CoP) in different planes and axes. *Method and materials:* The therapeutic program involved the application of proprioceptive neuromuscular facilitation techniques using repeated stimulation, performed concurrently with interactive exergaming tasks on the MIRA Rehab digital platform. Exercises were conducted on an unstable support surface (balance board) to stimulate postural adjustment. Quantitative measurements of postural control were collected using BTWalk software, focusing on CoP variability. *Results:* Comparative analysis of pre- and post-intervention data indicated a statistically significant reduction in the standard deviation values of CoP displacement in both the antero-posterior and medio-lateral directions. These findings support an improvement in static postural stability following the intervention. *Discussion:* Improvements observed are attributed to various factors: the engaging, gamified MIRA Rehab system boosted motivation; motor tasks across multiple planes enhanced neuromuscular activation; and a task-oriented approach facilitated sensorimotor learning through repetition and feedback. Although minor improvements in CoP control on a fixed surface were noted, they were not statistically significant, indicating that children with NMD might benefit more from dynamic stimuli that challenge balance and sensorimotor integration.

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These findings support previous research on the advantages of interactive virtual rehabilitation in pediatric neurorehabilitation, showing that exergames enhance balance control and improve therapy adherence. *Conclusions:* This study demonstrates that an exergame-based balance training program using the MIRA Rehab platform can produce statistically significant improvements in postural stability on unstable surfaces in children with neuromotor disabilities. The intervention was effective in reducing CoP displacement in both sagittal and frontal planes, indicating better control of the center of gravity during challenging postural tasks.

Keywords: physiotherapy, static balance, exergaming, neuromotor rehabilitation

INTRODUCTION

Exergame-Based Rehabilitation Platforms: Mechanisms and Clinical Effectiveness

The Role of Gamification and MIRA Rehab Technology

Gamification is becoming increasingly common within the field of rehabilitation, where it is viewed as a beneficial strategy to enhance patient engagement, enthusiasm, and overall involvement in therapy. The MIRA Rehab platform is an exergame rehabilitation tool that requires specific hardware, including a computer and a motion tracking sensor. This system is implemented in physiotherapeutic approaches for various physical deficiencies to improve physical coordination, stability, gross motor skills in the upper and lower limbs, attention, eye-hand coordination, and sensorimotor abilities.

Hardware Capabilities and Application Across Populations

The Kinect 360 Xbox sensor is frequently incorporated into these systems due to its excellent accuracy in recognizing joint movements. Consequently, this sensor is often utilized as a reliable tool for assessing the range of motion (ROM) of both the lower and upper limbs (Guess et al., 2016; Seo et al., 2016; Lahner et al., 2015; Hawi et al., 2014). This specific exergame hardware integrates virtual reality and is applicable across all ages and genders for rehabilitation programs treating either orthopedic or neurologic deficiencies.

Clinical Effectiveness in Adult and Pediatric Rehabilitation

Applications in Stroke and Fall Prevention

Games-based exercises, or 'Exergames,' have demonstrated clinical efficacy in multiple domains. A systematic review and meta-analysis conducted by Corbetta et al. (2015) provided supporting evidence that these exercises help improve balance and reduce variables related to falls risk following a stroke by enhancing mobility and walking speed. Furthermore, clinical interventions have indicated that exergame programs successfully assist older community-dwelling individuals in improving their balance after experiencing a stroke (Koh et al., 2020). MIRA Rehab exergames also represent a cost-effective strategy for preventing falls in assisted living facilities for people aged 55 years or older, showing improvements in balance, pain, and fear of falling (Stanmore et al., 2019).

Treatment for Children with Cerebral Palsy (CP)

Low-cost technology video games hold potential as valuable rehabilitation resources for children, particularly those with cerebral palsy. A gaming system based on non-immersive virtual reality (Xbox 360 KinectTM) showed gains in the independence of activities of daily living when used as a supplement to traditional rehabilitation treatment for children with CP (Luna-Oliva el al., 2013). Additionally, customized interactive video games provided by MIRA Rehab, used in conjunction with the Kinect 360 Xbox sensor, have served as an occupational therapy scoring system for evaluating bilateral upper limb performance and function in children with cerebral palsy (Moldovan et al, 2014).

Neuromotor Principles and Mechanism of Action

Postural Stability and Reflexes

Research has been conducted to analyze the effect on static balance when applying a proprioceptive neuromuscular facilitation (PNF) technique during a physiotherapeutic program utilizing Mira Exergames for orientation development in children with neuromotor disabilities. Maintaining the body on the vertical axis—a state defined as stabilizing the body—requires aligning the entire body such that the projection of the Center of Pressure (CoP) falls within the body's supporting base (Yoshida et al, 2022). When imbalances or deviations occur in the latero-lateral or antero-posterior planes, the cortex involuntarily executes the postural recovery reflex (Macie, 2021; Promsri, Mohr, & Federolf, 2021).

Neuroplasticity and Motor Learning

Conscious neuro-muscular activity facilitates recovery when the body is stimulated through conscious, induced imbalance (Sandoval-Munoz & Haidar, 2021; Sousa et al, 2023). For individuals with special educational needs (SEN) who exhibit reduced motor skills, learning is promoted by stimulating the cortex through imitation. Furthermore, motor skills are created through neuroplasticity, which is encouraged by the frequent repetition of a movement or repeated reflex stimulation achieved via proprioceptive neuromotor facilitation (PNF).

Benefits of Isometric Training

Isometric exercise is beneficial for managing imbalance and improving overall well-being (Šarabon & Kozinc, 2020). Its effectiveness is linked to its capacity to increase muscle strength, improve blood flow regulation, boost cardiovascular fitness, and support the adjustment of autonomic function (Zhao et al, 2022). Therapeutic programs that incorporate optimal and customized isometric training techniques based on individual needs can enhance cardiovascular health and stability (Kounoupis et al, 2020; Azeem & Zemková, 2022), providing patients with increased comfort and confidence to manage their daily activities.

The research studied the effect on static balance applying a proprioceptive neuromuscular facilitation technique during the performance of a physiotherapeutic program for orientation development using Mira Exergames on children with neuromotor disabilities.

METHODS AND MATERIALS

This study was conducted on a group of 10 children with neuromotor disabilities (NMD) and special educational needs (SEN), each with different diagnoses but all meeting the eligibility criteria for participation. These included:

- the ability to maintain balance for at least one minute on a balance board,
- the ability to sustain a static posture for a minimum of 10 seconds,
- the capacity to focus visual attention on a screen placed approximately 1.5 meters away for at least one minute, and
- the cognitive ability to perceive and process visual instructions.

The intervention focused on eliciting reflexive, uncontrolled postural rebalancing through combined motor, cognitive, and spatial orientation tasks, integrated into a rehabilitation program using the MIRA Rehab exergame platform. These tasks were performed on an unstable support surface (balance board), which added a proprioceptive challenge to the motor training (Sousa et al., 2023; Luna-Oliva et al., 2013).

Assessment Tools and Parameters

To evaluate static balance, we used the BTS P-Walk system, a validated gait and posture assessment tool based on plantar pressure sensors (Macie, 2021; Yoshida et al., 2022). The system allows detailed analysis of:

- static and dynamic plantar pressure,
- center of pressure (CoP) trajectory,
- postural asymmetries, and
- rotational displacements during stance.

The stabilometry module of the BTS P-Walk provides insights into the postural control mechanisms, particularly by measuring deviations in the sagittal (OX) and frontal (OY) planes. The test was administered under both eyes-open and eyes-closed conditions, enabling the analysis of oculomotor, vestibular, and proprioceptive contributions to balance.

This technology allows clinicians to compare patient data with normative reference values, providing an immediate interpretation of deviations in postural stability and plantar pressure distribution (Stanmore et al., 2019; Zhao et al., 2022).

Stabilometric Analysis Parameters

The key stabilometric parameters included:

- Standard deviation of CoP trajectory on the OX and OY axes,
- Total sway area, represented by an ellipse covering 90% of CoP points,
- Balance density curves in the sagittal and frontal planes.

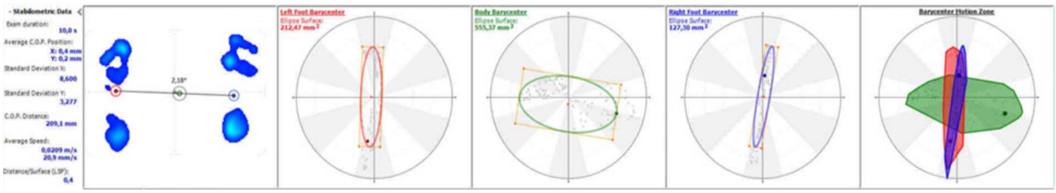


Fig. 1. Stabilometric evaluation with BTS P-Walk

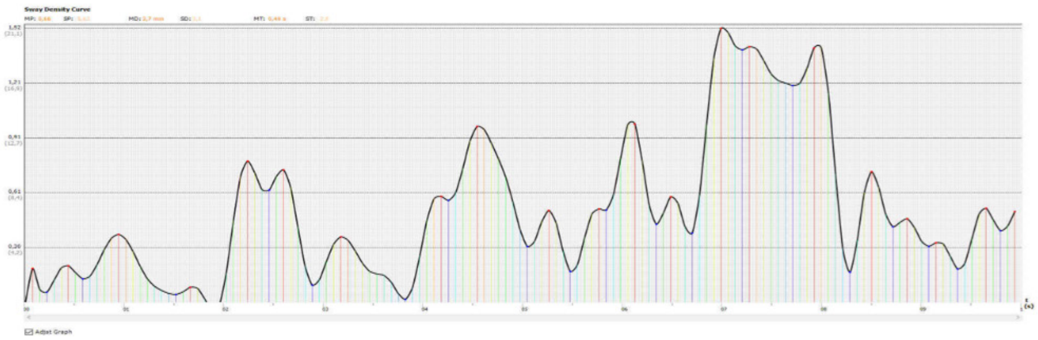


Fig. 2. Density balance curve on the OX and OY axes

Rehabilitation Protocol

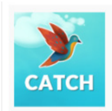
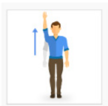
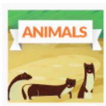
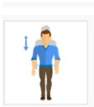
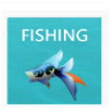
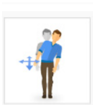
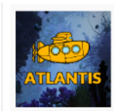
Each child participated in 10 therapy sessions over a period of one month (three sessions per week). Each session consisted of static balance training through MIRA Rehab exergames, conducted on the balance board to enhance proprioceptive feedback and neuromotor control (Tyng et al., 2017; Sattelmayer et al., 2016).

The exergames were designed to require multi-directional upper body movements, including:

- Shoulder flexion/extension,
- Shoulder abduction/adduction,
- Spinal lateral flexion and forward bending,
- Hip abduction.

These movements were tailored to the objectives of the games (Table 1), promoting engagement, motor learning, and reflexive balance recovery (Behan et al., 2022).

Table 1. Types of Combined Movements and MIRA Rehab Exergames applied in the research

Movement	MIRA games	Game Objective
 Shoulder abduction		Catch different images appearing on screen
 Hip abduction		Same game, performed using lower limb movements
 Shoulder flexion		Identify and select animals according to specific sounds
 Spine flexion		Catch as many fish as possible while avoiding traps
 Lateral spine flexion		Navigate a submarine to catch treasures and avoid bombs

Note: Combination of games and movements preset in MIRA Rehab to implement the program for each session - same game executed with one or two types of body movements, performed correctly, on maximum amplitude

Each game was executed with maximum movement amplitude and included preset combinations of body movements provided by MIRA Rehab.

Pre- and Post-Test Evaluation

The pre-test and post-test evaluations were conducted under identical conditions (time, place, equipment) to ensure measurement validity and reliability. Each participant's static balance was tested:

- First, on a fixed surface (ground), and
- Then, on a mobile surface (balance board).

Data were collected from the results generated by the BTS P-walk balance assessment software, for each member of the experimental trial group, following the pre and posttest static balance assessment - by pre and post evaluation. These results include objective stabilometric data obtained after evaluations that were performed by placing the software sensor on two surfaces - on the ground - considered the fixed surface and on the balance plate, considered the mobile surface. By comparing the two evaluations, a favorable evolution of the stabilometric data according to the provided data is observed (Figure 3a. and Figure 3b. for fixed surface and Figure 4a.and Figure 4b for mobile surface).

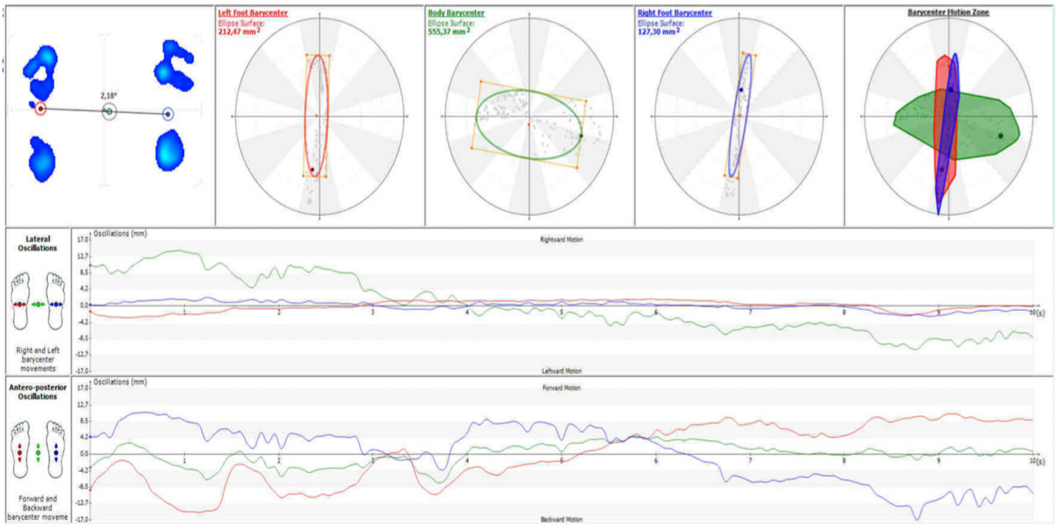


Fig. 3a. Pre-test static balance evaluation on fixed surface - results obtained from the BTS P-walk software

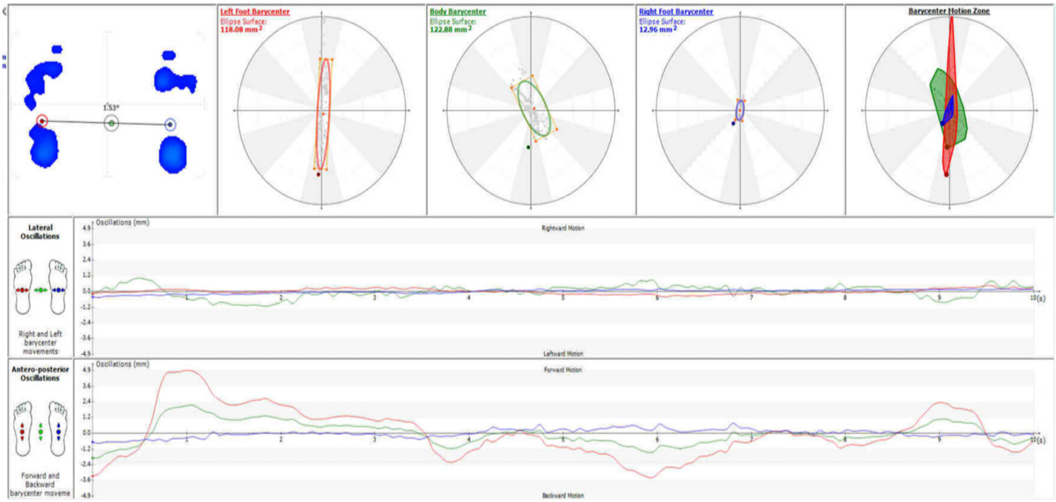


Fig. 3b. Post-test static balance evaluation on fixed surface - results obtained from the BTS P-walk software

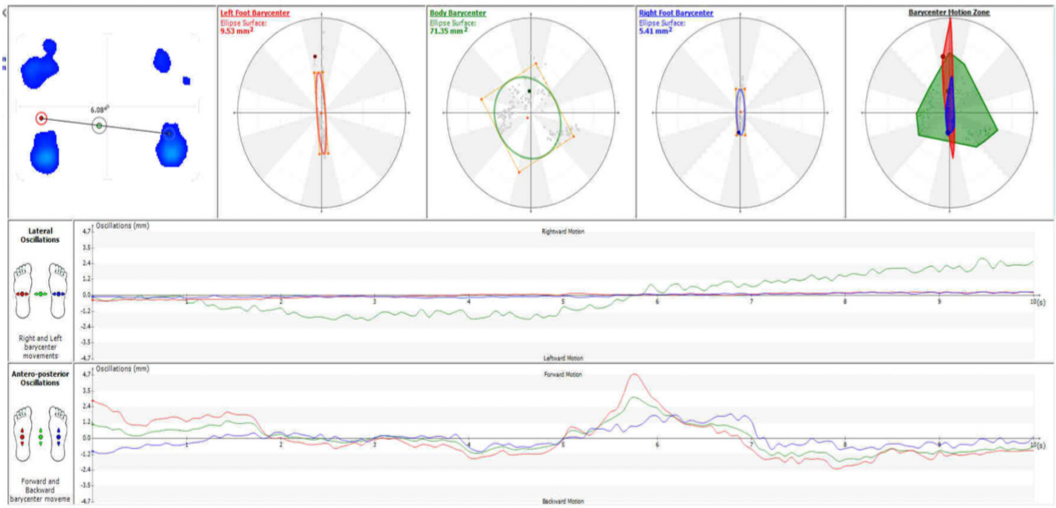


Fig. 4a. Pre-test static balance evaluation on mobile surface - Results obtained from the BTS P-walk software

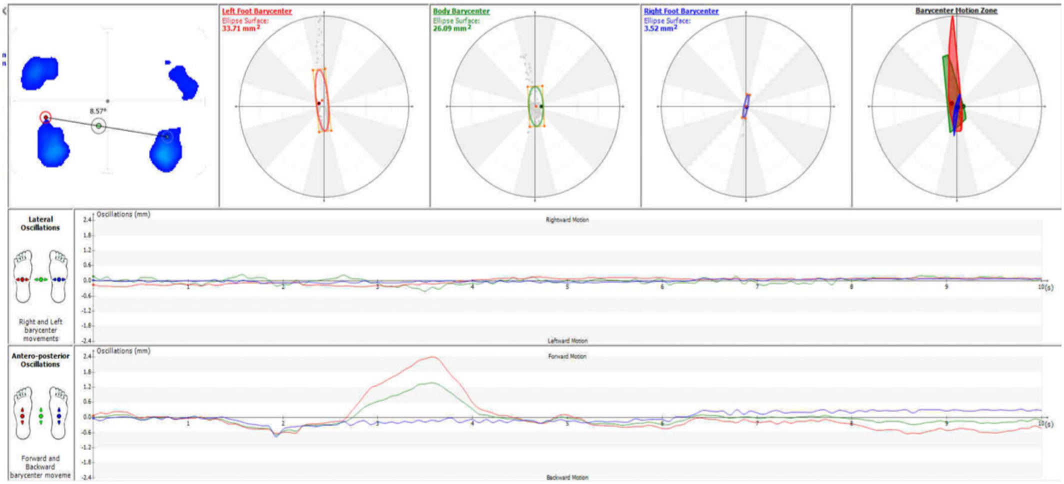


Fig. 4b. Post-test static balance evaluation on mobile surface - Results obtained from the BTS P-walk software

RESULTS

The data obtained from the BTS P-Walk balance assessment software were statistically analyzed using the Paired Samples T-test, in order to examine the differences between pre-test and post-test scores across multiple stabilometric parameters. The primary dependent variables were the standard deviations of Center of Pressure (CoP) displacements on both the sagittal (X-axis) and frontal (Y-axis) planes, recorded on both fixed and mobile surfaces.

Descriptive Statistics

Descriptive statistics, including means and standard deviations, were calculated for all measured variables. Table 2 presents the results of the pre- and post-test evaluations for each parameter.

Table 2. Descriptive Statistics of Pre-Test and Post-Test CoP Standard Deviations on Fixed and Mobile Surfaces

Pair	Condition	Mean	N	Std. Deviation	Std. Error Mean
1	Pre-test fixed X-axis SD	2.27	10	2.99	0.95
	Post-test fixed X-axis SD	1.39	10	1.41	0.45
2	Pre-test fixed Y-axis SD	2.63	10	2.25	0.71
	Post-test fixed Y-axis SD	2.11	10	1.63	0.52

Pair	Condition	Mean	N	Std. Deviation	Std. Error Mean
3	Pre-test mobile X-axis SD	8.08	10	3.0	0.95
	Post-test mobile X-axis SD	4.66	10	3.42	1.08
4	Pre-test mobile Y-axis SD	8.67	10	3.81	1.21
	Post-test mobile Y-axis SD	3.98	10	1.74	0.55

Note. N = number of participants; SD = standard deviation; Std. Error Mean = standard error of the mean.

Inferential Statistics

To determine the significance of the differences between pre-test and post-test scores, a **Paired Samples T-test** was performed for each variable. The results are summarized in Table 3.

Table 3. Paired Samples T-Test Results Comparing Pre-Test and Post-Test CoP Standard Deviations

Pair	Mean Difference	T	df	p (2-tailed)	95% CI of the Difference
1	0.88	1.1	9	.298	[-0.93, 2.70]
2	0.51	0.76	9	.469	[-1.02, 2.05]
3	3.43	4.35	9	.002	[1.64, 5.21]
4	4.69	4.12	9	.003	[2.11, 7.26]

Note. CI = confidence interval; df = degrees of freedom; p values are two-tailed.

Statistically significant differences ($p < .05$) were found for Pair 3 (mobile X-axis) and Pair 4 (mobile Y-axis), indicating a meaningful improvement in balance control on the mobile surface following the intervention.

For Pair 3, the mean post-test score ($M = 4.66$, $SD = 3.42$) was significantly lower than the pre-test score ($M = 8.08$, $SD = 3.00$), $t(9) = 4.35$, $p = .002$.

For Pair 4, the post-test score ($M = 3.98$, $SD = 1.74$) was also significantly lower than the pre-test score ($M = 8.67$, $SD = 3.81$), $t(9) = 4.12$, $p = .003$.

In contrast, Pairs 1 and 2, which correspond to standard deviations on the fixed surface (X-axis and Y-axis, respectively), showed a decrease in post-test values, but these differences were not statistically significant ($p > .05$).

Interpretation

These results suggest that the use of MIRA Rehab exergames performed on a balance board significantly improved postural control on unstable surfaces, particularly by reducing CoP variability in both sagittal and frontal planes. Improvements on stable surfaces were observed, but not at a statistically significant level.

DISCUSSION

The findings of this study support the efficacy of an exergame-based rehabilitation program using the MIRA Rehab system in improving static balance control in children with neuromotor disabilities (NMD) and special educational needs (SEN). The most notable outcome is the significant reduction in Center of Pressure (CoP) standard deviations on the mobile surface, both in the sagittal (X-axis) and frontal (Y-axis) planes, after ten intervention sessions.

As illustrated in Figure 5, a clear downward trend in CoP variability was observed between the pre-test and post-test assessments, with greater reductions in the mobile surface conditions. Specifically, post-intervention measurements showed significant improvements in postural control when balance was challenged by instability, reflecting increased proprioceptive responsiveness and motor coordination.

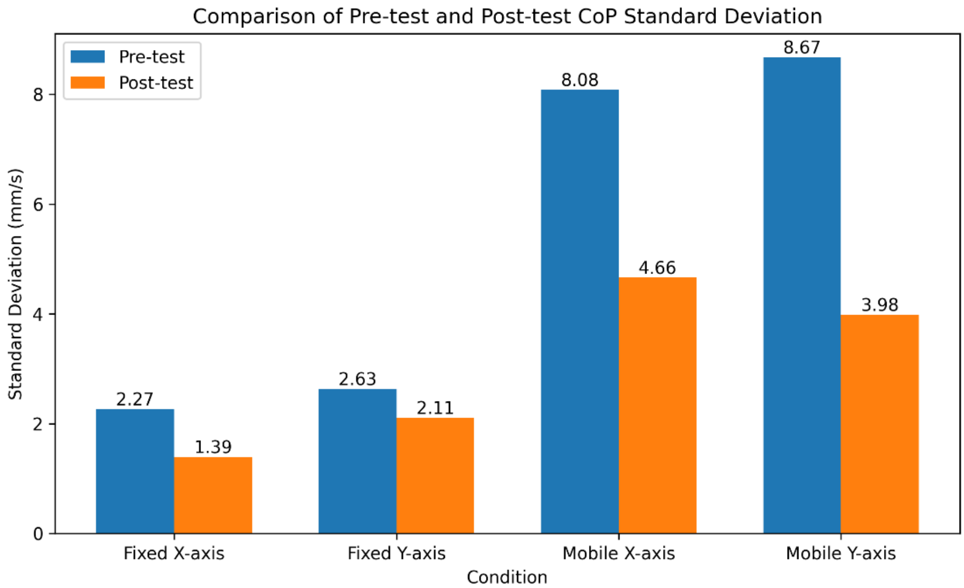


Fig. 5. Comparative Analysis of Pre-Test and Post-Test Center of Pressure (CoP) Standard Deviations on Fixed and Mobile Surfaces

These improvements are likely the result of multiple factors:

- The interactive, gamified format of the MIRA Rehab system enhanced engagement and motivation.

- The motor tasks performed in multiple planes (sagittal and frontal) likely promoted comprehensive neuromuscular activation.
- The task-oriented structure of the exercises encouraged sensorimotor learning through repetition, feedback, and real-time correction.

In contrast, although minor improvements were noted in CoP control on the fixed surface, these were not statistically significant ($p > .05$). This outcome suggests that postural systems in children with NMD may respond more readily to dynamic or unstable stimuli, where greater demand is placed on sensorimotor integration and balance adjustment.

These results align with previous research highlighting the benefits of interactive virtual rehabilitation platforms in pediatric neurorehabilitation. Several studies have reported that exergames not only stimulate balance control and postural symmetry but also improve adherence to therapy protocols due to their engaging and adaptive nature.

CONCLUSIONS

This study demonstrates that an exergame-based balance training program using the MIRA Rehab platform can produce statistically significant improvements in postural stability on unstable surfaces in children with neuromotor disabilities. The intervention was effective in reducing CoP displacement in both sagittal and frontal planes, indicating better control of the center of gravity during challenging postural tasks.

Although improvements on fixed surfaces were also noted, these did not reach statistical significance, suggesting that the intervention's benefits are more pronounced under dynamic balance conditions.

These findings support the integration of interactive digital tools in pediatric rehabilitation, offering a motivating, measurable, and adaptive approach to motor recovery. Further research with larger cohorts and controlled study designs is necessary to confirm these outcomes and explore additional benefits in functional mobility, daily living activities, and long-term motor autonomy.

RESEARCH LIMITATIONS

One of the main limitations encountered in this research was the difficulty of involving certain students in therapeutic programs that incorporate virtual materials. This was primarily due to challenges related to spatio-temporal orientation, visual processing disorders, and attention deficits, particularly among participants diagnosed with autism spectrum disorders, hyperkinesia, or ADHD.

FUTURE RESEARCH DIRECTIONS

The effectiveness of static balance training through repetitive stimulation of postural righting reflexes—using the balance board in conjunction with MIRA Rehab software—on improving functional independence in activities of daily living (ADLs) in children with neuromotor disabilities will be further investigated in the first author's doctoral thesis, involving a larger and more diverse sample of participants.

CONFLICT OF INTEREST

None declared.

AUTHORS CONTRIBUTION

All authors designed the study, contributed to the data collection, analyzed, accessed and verified the data. All authors drafted the initial manuscript, interpreted the data and approved the decision to submit the manuscript.

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IS NECK PAIN THE EFFECT OF ANKLE INSTABILITY?

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ABSTRACT. *Introduction*: The myofascial chains concept along with tensions and disruptions analysis in chain connectivity contribute to neck pain understanding. Moreover, this concept justifies the existence of other causes, not just local impairements, that promote and maintain cervical dysfunctions. *Objective:* This study aims to investigate the correlation between neck disability and ankle instability by analyzing the relationships between Neck Disability Index (NDI) and Numeric Rating Scale (NRS) with Cumberland Ankle Instability Tool (CAIT) and Y Balance Test (YBT). *Material and Methods*: 60 participants were assessed for ankle instability using CAIT and dynamic postural control through YBT. Cervical disability and pain intensity were quantified using NDI and NRS, respectively. Correlation analyses were performed to identify associations between distal (ankle) and proximal (cervical) parameters. *Results*: The analysis revealed a very strong positive correlation between NDI and pain intensity (r-0.884, p= 0.000), a strong significant negative correlation was observed between NDI and CAIT (r= -0.595, p= 0.000). Moderate negative correlations were found between NDI and Y Balance Test scores for the both the right (r= -0.407, p= 0.001) and left limbs (r= -0.406, p= 0.001). In addition, pain intensity showed moderate negative correlations with CAIT scores (r= -0.567, p=0.000), and with Y Balance test (r= -0.464, p=0.001 for right limb and r= -0.389, p=0.002 for the left limbs). *Discussion:* Preliminary findings indicate that reduced ankle stability and lower YBT scores are associated with higher levels of cervical disability and pain. Most participants reported a good ankle stability based on CAIT scores, their performance

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on the Y Balance Test indicated reduced dynamic balance. This discrepancy may be explained by the subjective nature of CAIT questionnaire which reflects individual's perception of stability rather than objective neuromuscular control. Chronic ankle instability can often be compensated for by other postural segments, leading to a false sense of stability. *Conclusions:* The observed correlations suggest that impaired ankle function may contribute to altered cervical motor control and discomfort through global myofascial and neuro-sensory mechanisms. A global assessment and treatment approach, addressing both distal and proximal components could improve outcomes in subjects with cervical dysfunction.

Keywords: cervical disability; ankle instability; myofascial chain; cervical pain

INTRODUCTION

The non-specific cervical pain, one of the most common musculoskeletal disorders (Safiri, et al., 2020), is considered the second most frequent after low back pain (Hoy et al., 2010). Its impact is not limited to the local area, but influences the entire motor control system, with consequences for posture, stability, and coordination of movements (Phapatarinan et al., 2024).

The motor control of the cervical spine is mainly impaired after trauma or poor posture, as observed in clinical practice. Although pain is often present, proprioceptive errors are also present identified by measuring the error in repositioning the head and neck (Heggli et al., 2023). In this regard, improved proprioception at cervical level reduces the risk of injury and, by extension, the perception of pain.

Due to its implications in the context of motricity, proprioceptive control is essential for generating and facilitating the execution of movements in a smooth manner, and eventually integrating them into movement patterns (Moon et al., 2021), which may become a preferred movement pattern when relevant proprioceptive feedback is available (Dean, 2013). For this reason, proprioceptive feedback systems are under continuous research (Marasco & de Nooij, 2023).

Under the perspective of neuromuscular functionality, fascial integrity is an essential element for locomotion, interaction with the environment, and overall physical well-being (Slater et al., 2024). The role of myofascial chains is to integrate coordinated movements, transmit tension, accommodate varied stimuli, and transform proprioceptive information into a postural or reactive response (Almansoof et al., 2023).

Myofascial chains represent a modern conceptualization of the musculoskeletal system by integrating muscles and fascia into a continuous functional network that allows the transmission of mechanical forces and tensions at a distance, crossing the anatomical borders of a body segment (Bordoni et al., 2023). They describe the three-dimensional organization of fascia as an interconnected system comprising muscles, tendons, aponeuroses, and connective structures. In this way, movement and posture do not depend on the local action of a single structure, but on the whole system working together as a unified entity (Ajimsha et al., 2020).

Myofascial chains shift the generalized perspective and include the components in an integrated system, not a cumulative one (Schleip & Wilke, 2021). Therefore, if muscles are classified biomechanically according to insertion, origin, and action, their role is limited, in terms of significance, to the mobilization of one or more joints. Their activity must be related to a global context, in which muscle groups act interdependently and influence each other to support biomechanical functions within optimal parameters (Avin et al., 2015).

Balance and vertical posture are maintained by the involvement of the superficial back line in the stability of the pelvis and spine, both statically and dynamically (Gugliotti et. al., 2025). It also protects the joints and spine by absorbing and dispersing the forces generated during dynamic activities.

The mobility of the whole chain is mainly influenced by two of its components: the plantar fascia and the suboccipital muscles (Myers, 2020). The plantar fascia, through numerous nerve endings, contributes to sensory perception and motor feedback that directs postural adaptation reactions and balance (Hu et al., 2023). The suboccipital muscles represent the functional center of the chain that obeys eye movement and coordinates head and neck orientation, and implicitly inhibits and facilitates the muscles along the spine (Sung, 2022).

The myofascial components of the superficial back line are represented by the plantar fascia, Achilles tendon, triceps surae, hamstrings, sacrotuberous ligament, sacro-lumbar fascia, spinal erectors, and epicranial fascia (Williams & Selkow, 2019).

Through biomechanical analysis of movements, a correlation can be made between the fascial continuum, muscle tone and the area where pain is present. Movement patterns and postural attitudes analysed from the perspective of myofascial lines can explain the sequence of painful processes and provide clues about future decompensations. Thus, trauma to the ankle will have an immediate effect on the tibiotarsal joint and, most likely, a delayed effect on the most distant element of the chain that integrates it, for example, the cervical region.

I consider that the superficial back line provides an integrated perspective on movement and posture, explaining how a local dysfunction, such as ankle instability, can influence distant segments, such as the cervical area.

Thus, while neck pain is not "an ankle problem" in isolation it can be a manifestation of global dysfunction within the postural system, where the ankle acts as a critical contributor to the chain of compensations. Recognizing this relationship supports the need for global assessment and treatment addressing both distal and proximal segments to restore balance and reduce symptoms, due to inconsistent distribution patterns and the incertitude of primary origins of referred pain location (Jin et al., 2023).

MATERIAL AND METHODS

This article presents a cross-sectional correlational analysis that represents a sub-analysis from a larger study conducted on 60 participants. Data were collected at baseline (initial evaluation) before any intervention. The research design was chosen because it allows the identification of functional interconnection between variables, which is essential when the goal is to understand functionalities, rather than treatment effects.

The aim of the study was to investigate the relationship between cervical disability, pain intensity, ankle instability, and postural balance. The objective was to emphasize that cervical pain may be related not only to local disfunctions but also to distal impairments, particularly at the ankle level. By exploring this correlation the study highlights the importance of a global, myofascial chain-oriented assessment rather than a purely symptomatic approach.

Participants

The participants, aged between 20 and 69 years (M= 47.25; SD= 12.13) - 42 females and 18 males. The mean age for female participants was 46.71 years (SD= 12.63) and for the male participants was 48.50 years (SD=11.16). Each participant had a diagnosis of nonspecific cervicalgia, that had been present for at least three months, absence of acute trauma and ability to perform balance test. Participants with neurological, vestibular or systemic disorders that could affect postural control were excluded.

Procedure

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. All participants signed an informed consent prior to inclusion in the study.

The assessments were carried out in two different locations: Iași Clinical Rehabilitation Hospital and a private health care clinic in Iași County, Romania.

All participants completed questionnaires designed to evaluate cervical disability (NDI), ankle instability (CAIT) and pain intensity (NRS) followed the Y Balance Test. All assessments were performed under standardized conditions, in a controlled environment, by the same examiner to ensure data consistency and reliability.

Materials

The Neck Disability Index was used to assess the level of functional impairment related to cervical pain.

The Cumberland Ankle Instability Tool was applied to evaluate the degree of functional ankle instability.

The Numerical Rating Scale was used to quantify the subjective perception of pain intensity reported by each participant.

The Y Balance Test was conducted for both sides, right and left, measuring maximal reach distances in the anterior, posteromedial, posterolateral directions, to evaluate dynamic balance and neuromuscular control of the lower limbs.

Data analysis

Data were analyzed using SPSS software (version 20), the normality of data distribution was tested using Shapiro-Wilk test. The results indicates that variables are non-parametric, ($p<0.05$), allowing for the use of the Spearman correlation coefficient to determine the relationships between variables.

RESULTS

Table 1. Spearman's correlation between: NDI, CAIT, NRS, Y Balance Test

VARIABLES		NDI	CAIT	NRS	TestY_balance_R	TestY_balance_L
NDI	r	1.000	-.595**	.884**	-.407**	-.406**
	p	.	.000	.000	.001	.001
CAIT	r	-.595**	1.000	-.567**	.239	.177
	p	.000	.	.000	.065	.176
NRS	r	.884**	-.567**	1.000	-.464**	-.389**
	p	.000	.000	.	.000	.002
TestY_balance_R	r	-.407**	.239	-.464**	1.000	.823**
	p	.001	.065	.000	.	.000
TestY_balance_L	r	-.406**	.177	-.389**	.823**	1.000
	p	.001	.176	.002	.000	.

Variable	NDI	CAIT	NRS	TestY_R	TestY_L
NDI	1.00	-0.60	0.88	-0.41	-0.41
CAIT	-0.60	1.00	-0.57	0.24	0.18
NRS	0.88	-0.57	1.00	-0.46	-0.39
TestY_D	-0.41	0.24	-0.46	1.00	0.82
TestY_S	-0.41	0.18	-0.39	0.82	1.00

Fig. 1. Spearman's correlation between: NDI, CAIT, NRS, Y Balance Test

The analysis (Table 1 and Figure 1) revealed a very strong positive correlation between NDI and pain intensity (r=0.884, p= 0.000), a strong significant negative correlation was observed between NDI and CAIT (r= -0.595, p= 0.000).

Moderate negative correlations were found between NDI and Y Balance Test scores for the both the right (r= -0.407, p= 0.001) and left limbs (r= -0.406, p= 0.001). In addition, pain intensity showed moderate negative correlations with CAIT scores (r= -0.567, p=0.000), and with Y Balance Test (r= -0.464, p=0.001 for right limb and r= -0.389, p=0.002 for the left limbs).

Weak correlation, but positively were found between CAIT and Y Balance Test, not statistically significant.

Regarding the Y Balance Test scores for the left and right sides were strongly and positively correlated (r=0.823, p= 0.000), confirming internal consistency between the two measurements.

DISCUSSION

The analysis of initial correlations using Spearman's coefficient (Table 1) revealed significant relationships between cervical disability (NDI), pain, ankle instability (CAIT) and postural balance measured by the Y Balance Test, all of which are illustrated in Figure 1.

The NDI score showed a very strong positive correlation with pain intensity, confirming the direct impact of pain on the level of perceived disability, as stated by Czępińska et al. (2023). Significant negative correlations were also observed between the NDI and postural balance on both the right and left lower limbs, suggesting that a higher degree of cervical disability is associated with poorer postural control, similar to the relationship analyzed by Wah et al. (2022) between the NDI and static balance.

As pain increases, dynamic balance is more affected, aspect confirmed by the negative correlation between the Y Test of the right and left lower limbs and the degree of pain, also confirmed by Aslıyüce et al. (2022). This fact can be observed in practice through the anterior position of the head, which causes changes in the position of the center of gravity, altering balance. In other circumstances, the anterior position of the head and presence of cervical pain lead to compensatory strategies to maintain balance, which affects static posture and dynamic stability, especially in the sagittal plane.

The CAIT score correlated negatively with NDI and pain, indicating a possible influence of ankle instability on cervical functional status. However, correlations between the CAIT score and the Y Test were not statistically significant.

Although the literature suggests a relationship between ankle instability and functional balance (Cruz-Diaz et al., 2015), and most participants reported a good ankle stability based on CAIT scores, their performance on the Y Balance Test indicated reduced dynamic balance. This discrepancy may be explained by the subjective nature of CAIT questionnaire which reflects individual's perception of stability rather than objective neuromuscular control. Chronic ankle instability can often be compensated for by other postural segments, leading to a false sense of stability. In contrast, the Y Balance Test provides an objective measure of dynamic postural control, which depends not only on local ankle stability but also on the integration of proprioceptive input from the cervical region and the global postural system.

CONCLUSIONS

The findings of this study demonstrate significant associations between cervical pain and ankle instability. These results support the concept of a functional interdependence between the cervical and ankle regions, mediated through superficial back line and global sensorimotor pathways.

Clinically, this highlights the importance of a global assessment and treatment approach, addressing not only the symptomatic cervical level, but also distal components such as the ankle that contribute to postural alignment and neuromuscular stability.

AUTHOR CONTRIBUTIONS
All authors contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

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ASSESSING THE AVAILABILITY OF SPORTS FACILITIES AND EQUIPMENT IN TRANSYLVANIAN SCHOOLS: A CROSS-SECTIONAL ANALYSIS

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ABSTRACT. *Introduction:* Physical education facilities and equipment represent a fundamental resource for ensuring effective teaching and learning in schools. Their availability and quality directly influence the conditions in which students participate in physical education. *Objective*: This study aimed to assess the availability and quality of physical education facilities and equipment in schools across Transylvania, Romania, in accordance with the national standards set by the Romanian Ministry of Education (order no. 3399/2017). *Material and methods*: A questionnaire was distributed to physical education teachers working in the region, collecting data on the presence, number, condition, and use of gymnasiums, sports halls, and outdoor physical education areas, as well as the quantity and perceived quality of sports equipment. *Results*: The results showed that most schools had one gymnasium (78.2%), while 7.3% had none. A significant positive correlation was found between the number of enrolled students and the number of indoor sports facilities. On average, one gymnasium served 457 students (sd = 309.37). A total of 92.7% of schools reported having suitable outdoor areas for physical education classes. 4did not meet the recommended quantities outlined by national regulations. While the quantity of equipment was insufficient, the perceived quality of facilities and equipment was generally rated as good. *Discussion*: These findings were consistent with previous research highlighting inequalities in the distribution of school infrastructure and resources. The reported adequacy of quality, despite quantitative shortages, reflected broader issues described in similar educational contexts. *Conclusion*: The findings highlight the need for targeted improvements in school infrastructure and resource allocation to support quality physical education.

Keywords: school sports infrastructure; physical education equipment; Romanian schools; educational facility standards.

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INTRODUCTION

Physical education (PE) is a compulsory subject in the Romanian national curriculum, delivered either outdoors or in specially designated gymnasiums or sports facilities. As the only subject focused primarily on physical development, PE offers students structured opportunities to enhance their motor skills and physical fitness under the supervision of qualified instructors. It also contributes significantly to students' overall physical and mental well-being.

Beyond the school context, leisure-time physical activity has also been shown to play a crucial role in supporting a healthy lifestyle and overall well-being. Gherman, Monea, Gombos, and Patrascu (2021) emphasize that recreational exercise contributes not only to physical health, but also to stress reduction and mental balance, regardless of one's profession. Their findings indicate that the vast majority of participants (94.4%) perceive diet and nutrition as a key component of physical activity, and that sport is widely regarded as one of the most effective strategies for relaxation after stressful days. Such evidence underlines the importance of ensuring access to diverse opportunities for physical activity both within and beyond the school setting.

The physical and psychological benefits of regular physical activity are well established (Köse & Kirişci, 2020; Uzun Dönmez & İmamoğlu, 2020; Talbot, 2001; Parisi et al., 2015). Within the school setting, gymnasiums equipped with diverse tools and infrastructure allow students to engage in more complex and varied movement experiences. According to Brendon et al. (2016), the availability of a wide range of ground-based equipment is essential for facilitating complex physical tasks among children. Delidou et al. (2015) further emphasize that a supportive school environment plays a key role in promoting physical activity engagement and overall health in preadolescents.

This is supported by Verstraete et al. (2006), who found that simply providing game equipment during recess periods significantly increased moderate-to-vigorous physical activity among elementary school students. Similarly, Fein et al. (2005) concluded that the more opportunities the environment offers for physical activity, the more likely children are to engage in it. Willenberg et al. (2010) showed that even simple environmental modifications, such as playground markings, can meaningfully increase children's physical activity levels during school hours. Cradock et al. (2007) also reported a strong positive association between school physical environments and children's physical activity levels.

Bendíková (2016) demonstrated that incorporating equipment-supported training in PE classes has a positive effect on postural development, highlighting the functional importance of diverse physical tools. However, in Romania, such approaches are often hindered by structural limitations. Compared to the European average of 110.9 ± 33.1 minutes of PE per week, Romanian students receive approximately 20 minutes less (Balla, Boros-Bálint, & Szatmári, 2022; European Commission, 2013). According to UNESCO (2014), primary and lower secondary students in Romania receive on average 95 minutes of physical activity per week, while high school students receive only half that amount.

The limited time devoted to PE is further compounded by poor infrastructure. Curticăpean (2011) and Iconomescu (2016) note that many schools and universities in Romania lack sufficient access to sports facilities, and the number of gymnasiums remains low relative to the school-age population. This issue is exacerbated by limited financial investment and institutional support for physical education, which often results in reduced access to quality PE and equipment.

Negru et al. (2020) results suggest that the pandemic, combined with poorly equipped school facilities, further limited opportunities for consistent physical activity. Despite the critical role of school infrastructure in supporting physical development, there is limited empirical data on the availability and distribution of sports halls and PE equipment in Romanian schools—particularly in the region of Transylvania. Therefore, the present study aims to provide a cross-sectional overview of the current state of school sports infrastructure in this region, contributing to a better understanding of infrastructural inequalities and opportunities for development in the Romanian educational system.

Aims of the study

The primary aim of this study was to evaluate the condition and availability of school sports facilities and physical education (PE) equipment in a sample of schools across Transylvania, Romania. The analysis was conducted in reference to the minimum standards outlined by the Romanian Ministry of Education (Order No. 3399/2017).

Specific objectives included:

- To assess the number, size, and condition of gymnasiums and outdoor PE areas in the participating schools.
- To evaluate the availability, usage frequency, and perceived quality of PE equipment.
- To identify gaps between existing resources and official standards.
- To explore the relationship between facility/equipment availability and the organization of extracurricular sports activities.
- To document teachers' needs and preferences regarding additional equipment.
- To examine whether infrastructure and equipment levels are associated with student participation in sports competitions organized by the Ministry of Education.

MATERIAL AND METHODS

Sample description

Data were collected from 55 schools located in Transylvania, Romania. None of the participating institutions are private or sports-specialized schools. The available facilities and their associated equipment are primarily used during physical education classes. In 36 schools (65.5%), extracurricular sports activities are also organized for students.

The sample includes both rural and urban institutions, with 45% of the schools located in rural areas and 55% in urban settings. Schools were selected from the following counties: Covasna (26 schools, 47.5%), Harghita (17 schools, 30.9%), Mureș (4 schools, 7.3%), Cluj (2 schools, 3.6%), Satu Mare (2 schools, 3.6%), Sălaj (2 schools, 3.6%), Maramureș (1 school, 1.8%), and Alba (1 school, 1.8%).

Data collection and instrumentation

This study was based on a descriptive cross-sectional research design. Data was collected using a self-administered questionnaire developed by the research team. The questionnaire was completed by physical education teachers employed at the participating schools. In designing the survey, we used as reference the official document issued by the Romanian Ministry of National Education (Ministerial Order No. 3399/2017), which outlines the infrastructure and equipment requirements for physical education.

The final version of the questionnaire included 20 items. Eight questions collected demographic information related to the school's location, type, and the characteristics of the teaching staff. The remaining 12 items focused on the availability and condition of indoor sports halls and outdoor spaces designated for physical education. One question block was dedicated to assessing both the quantity and subjective quality of sports equipment considered essential for conducting physical education lessons.

Procedure and data processing

Data collection took place between October 2024 and April 2025. During this period, physical education teachers received the questionnaire either as a printed version distributed in person or in digital format via email. The questionnaire was sent to 100 schools across the region. A total of 75 responses were returned, resulting in a response rate of 75%. However, due to incomplete or inconsistent answers, only 55 questionnaires were retained for analysis.

To ensure clarity and reliability, the questionnaire was pretested with a small group of physical education teachers prior to the full-scale data collection. The aim of the survey was to assess the availability and condition of sports facilities, the extent and quality of equipment use, and the challenges encountered by PE teachers in implementing effective physical education programs.

Statistical analysis

Descriptive and inferential statistical methods were used to analyze the data. Descriptive statistics, including means (*M*), standard deviations (*SD*), frequencies, and percentages, were calculated to summarize the characteristics of the schools, facilities, equipment, and teacher-reported evaluations.

To test for associations between variables, Pearson correlation coefficients were calculated (e.g., between the number of students and the number of sports facilities). Independent-samples t-tests were used to compare means across groups (e.g., comparing student-to-gymnasium ratios with national benchmarks). In addition, chi-square tests (χ^2) were applied to examine the relationship between categorical variables (e.g., presence of court markings and organization of extracurricular sports activities).

All statistical analyses were conducted using IBM SPSS Statistics software (Version 26.), with the level of statistical significance set at $p < .05$.

RESULTS

Descriptive results of school infrastructure and staffing

The data collected from 55 schools covered a total of 21,136 students, 61 gymnasiums, and 55 physical education (PE) teachers. On average, the number of students per school was 457 (*SD* = 309.37). The average number of PE teachers per school was 2.11 (*SD* = 1.08).

Most schools (78.2%) had only one gymnasium. Six schools (10.9%) were equipped with two gymnasiums, and two schools (3.6%) had three gymnasiums. However, four schools (7.3%) reported having no gymnasium at all. On average, schools had 1.11 (*SD* = 0.56) gymnasiums.

In terms of facility amenities, 74.5% of the gymnasiums were equipped with changing rooms, while only 58.2% had access to showers. These findings indicate significant variability in the basic infrastructure available for physical education in the assessed schools.

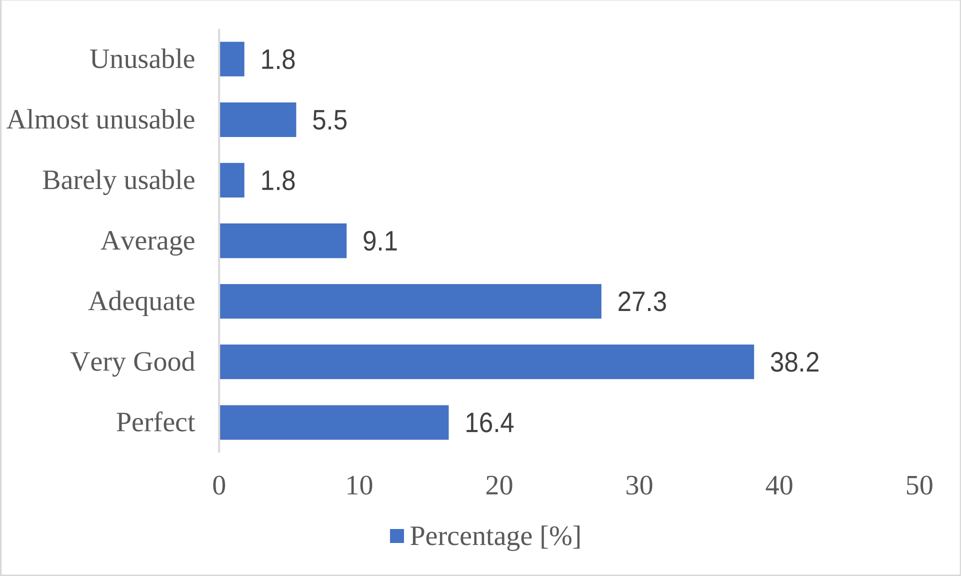

Figure 1. Distribution of sports equipment quality ratings in percentages.

Gymnasium size and perceived quality

The average surface area of the gymnasiums was 503.7 m² (*SD* = 580.25). Only nine schools (17.6%) had gymnasiums that met the standardized size requirements for school sports facilities (20 × 40 meters).

Teachers generally rated the condition of the gymnasiums positively. On a 7-point Likert scale (1 = unusable, 7 = excellent), 91.0% of the respondents rated the condition of their school's gymnasium as average or better. The overall average rating was 5.35 (*SD* = 1.37). However, in one case (1.8%), the gymnasium was reported to be in an unusable condition. Figure 1 also illustrates this.

Outdoor facilities for physical education

A total of 51 schools (92.7%) reported having at least one outdoor area suitable for conducting physical education classes. Among these, 30.9% of the surfaces were paved with concrete or asphalt, 25.5% were covered with artificial turf, and 18.2% consisted of paved stone surfaces. An additional 18.2% of the outdoor courts were concrete or asphalt surfaces equipped with appropriate sport-specific line markings for various games. Furthermore, 13 schools (23.6%) had more than one outdoor facility usable for physical education classes. The utilization of these spaces was reported to be significant: according to the teachers, approximately 50.4% of their lessons were conducted outdoors, indicating the essential role of these areas in compensating for the limited indoor space available in some institutions.

Markings and flooring quality of gymnasiums

In 69.1% of the gymnasiums, court markings were available for at least one sport. Teachers were asked to rate the quality of these markings on a 7-point Likert scale (1 = unusable, 7 = excellent), resulting in an average score of 5.86 (SD = 0.24), which can be interpreted as "very good." Similarly, the quality of gymnasium flooring was rated at an average of 5.46 (SD = 0.55), indicating a generally positive assessment.

The most common types of sport-specific court markings were for basketball (60.0%), handball (49.1%), football (38.1%), volleyball (34.5%), and tennis (29.0%).

A chi-square test revealed a statistically significant association between the presence of markings for basketball (p = .003) and handball (p = .005) and the organization of extracurricular sports activities. This suggests that the availability of sport-specific markings in gymnasiums is positively related to the likelihood of offering after-school sports programs in those disciplines.

Availability of sport-Specific equipment and its relation to extracurricular activities

With respect to ball sports, the average number of footballs available across schools was 8.27 (SD = 5.28), handballs 10.18 (SD = 7.89), and basketballs 9.40 (SD = 7.83). The data indicate that schools with a greater supply of sport-specific equipment—particularly balls—were more likely to organize extracurricular activities in those respective sports.

Statistical analysis revealed significant associations between the quantity of available equipment and the frequency of sport-specific extracurricular programs. The number of basketballs was significantly associated with the likelihood of organizing basketball activities (p = .017), the number of handballs with handball activities (p = .001), and the number of footballs with football activities (p = .033). These findings highlight the practical importance of sufficient equipment availability in supporting diverse and frequent student engagement in sports.

Condition of sports equipment

The overall condition of sports equipment was assessed using a 7-point Likert scale (1 = unusable, 7 = excellent). Only four schools (7.3%) reported that their equipment was in flawless condition. When aggregating all responses, physical education teachers rated the overall quality of equipment at an average of 5.55 (*SD* = 1.29), corresponding to a “very good” classification.

Among the best-rated items were gymnastic bars and hoops, with an average score of 6.50 (*SD* = 0.70), followed by measuring tapes, which received an average of 6.16 (*SD* = 1.17). Wall bars, a frequently used fixture, were also considered to be in very good condition, scoring an average of 5.86 (*SD* = 1.20).

In contrast, the least well-maintained items were gym vaulting boxes (pommel horses), which received an average score of 4.94 (*SD* = 1.68), and table tennis tables, which were rated lowest at 4.23 (*SD* = 1.82). These results suggest considerable variation in the maintenance and renewal of equipment across schools.

Utilization and availability of equipment, and teachers’ needs

According to the respondents, 78.8% of the existing sports equipment is regularly used during physical education classes. Handballs were the most available item, with an average of 10.18 units per school (*SD* = 7.89). In contrast, gymnastic equipment was scarcely present: parallel bars (0.07 units, *SD* = 0.325), beams (0.13, *SD* = 0.43), pommel horses (0.15, *SD* = 0.44), and rings (0.13, *SD* = 0.34). These apparatuses were not only underrepresented but also largely deemed unnecessary by teachers, who indicated low demand for them.

Interestingly, teachers expressed the greatest need for additional items that were already among the more frequently available and utilized. Besides handballs (10.18, *SD* = 7.89), teachers reported having on average 9.49 gym mats (*SD* = 5.67), 9.40 basketballs (*SD* = 7.83), and 8.27 footballs (*SD* = 5.38). However, they still identified these same items as needing further supplementation: 9.25 additional handballs (*SD* = 9.43), 7.07 basketballs (*SD* = 7.07), 7.05 gym mats (*SD* = 6.54), and 7.02 weighted balls over 5 kg (*SD* = 7.64) were requested to improve working conditions and facilitate lesson planning.

Over the past five years, teachers reported taking students to Ministry of Education-organized sports competitions an average of 12.95 times (*SD* = 11.78). However, no significant correlation was found between the quantity of available equipment and participation in these events. This suggests that the decision to engage in official school competitions is influenced by factors other than equipment availability.

DISCUSSION

This study aimed to assess the current state of sports facilities and equipment in schools across Transylvania, Romania, in relation to the minimum standards set by the Ministry of Education (Order No. 3399/2017). The findings reveal significant disparities between the prescribed standards and the actual conditions observed in the surveyed schools.

On average, each gymnasium served approximately 457 students (*SD* = 309.37), which is consistent with data from the National Institute of Statistics in 2016, reporting 462 students per gymnasium in Transylvania (Iconomescu, 2016). This suggests that little progress has been made in the development of school sports infrastructure over the past five years. Notably, the student-to-gymnasium ratio in Transylvania remains below the national average of 593 students per gymnasium, indicating a regional advantage in facility distribution. This difference was statistically significant, $t(50) = -3.301$, $p = .002$, 95% CI [–235.81, –57.41].

A significant positive correlation was found between the number of students and the number of gymnasiums in the participating Transylvanian schools ($p = .031$). However, Iconomescu (2016) reported no such correlation when examining national-level data. This suggests that, within Transylvania, higher student populations may be associated with increased investment in sports infrastructure.

Outdoor areas suitable for physical education were present in 92.7% of the schools, and teachers reported conducting 50.4% of their PE classes in these areas. This aligns with the findings of Delidou et al. (2015), who found that the size and availability of schoolyards were positively associated with students' physical activity levels during breaks.

The overall quality of sports equipment was rated positively by physical education teachers, with an average score of $M = 5.55$ ($SD = 1.29$) on a 7-point Likert scale. Teachers reported regular use of 78.8% of the existing equipment, particularly items that were already available in greater quantities, such as handballs, gym mats, basketballs, and footballs. This suggests that teachers prioritize maintaining and supplementing frequently used equipment to improve teaching quality.

Previous research also highlights the strong relationship between leisure-time physical activity and health-related quality of life (Negru and András, 2015). Gherman, Gomboș, Pop, and Pătrașcu (2022) reported that a vast majority of young adults in their sample (97.3%) considered sport an important or very important part of their daily lives. Furthermore, two-thirds of participants (67.6%) indicated that they spent more time engaging in sport activities than using electronic devices. These findings emphasize the critical role of access to facilities and opportunities that support active lifestyles, particularly among youth populations. Ensuring adequate infrastructure in schools is therefore not only an educational necessity but also a determinant of students' long-term health and quality of life.

Șerban & Baciu (2017) show that structured programs combining physical activity, healthy nutrition, and social interaction improve group cohesion and children's quality of life.

Despite the generally good condition of the equipment, the quantity of sports equipment available in most schools falls below the recommended levels set by the Ministry of Education (Order No. 3399/2017). Additionally, teachers expressed a need for more of the same items they already use most frequently. On average, they indicated a need for 9.25 additional handballs (*SD* = 9.43), 7.07 basketballs (*SD* = 7.07), 7.05 gym mats (*SD* = 6.54), and 7.02 weighted balls over 5 kg (*SD* = 7.64).

Although teachers reported, on average, 12.95 (*SD* = 11.78) participations in Ministry-organized sports competitions over the past five years, no significant correlation was found between equipment availability and competitive participation. This indicates that the quantity of available equipment may not be the primary factor influencing a school's engagement in extracurricular competitions.

Taken together, these findings highlight a clear need for targeted investments in school sports infrastructure and equipment, especially in schools with large student populations. Improving the availability and quality of physical education facilities and tools is essential for promoting active lifestyles and the physical development of students. While infrastructure and equipment alone do not determine participation in formal sports competitions, they play a critical role in supporting daily physical activity and inclusive physical education programs.

CONCLUSIONS

This study provided a comprehensive overview of the current state of school sports infrastructure and equipment across a sample of schools in Transylvania, Romania. The results highlight persistent infrastructural gaps relative to national guidelines, including a shortage of gymnasiums and insufficient quantities of basic physical education equipment. Although many teachers rated the condition of existing facilities and equipment as generally good, the quantity and variety often fell short of the standards outlined by the Ministry of Education.

A notable finding was that the availability of certain types of equipment—particularly those already present in greater numbers—was associated with more frequent use during physical education lessons. This underscores the importance of not only expanding equipment inventories but also maintaining the quality of frequently used tools. However, the level of equipment did not predict participation in organized school competitions, suggesting that other factors, such as institutional support, school leadership, or logistical barriers, may also play a role.

To promote equitable access to physical education and to support students' physical development, targeted investments in infrastructure, equipment, and teacher support are necessary—particularly in schools with large student populations. Future research should explore the relationship between equipment availability, teaching practices, and long-term student outcomes, as well as strategies to ensure sustainable development of school sports infrastructure across both urban and rural regions.

Limitations of the study

While the present study provides valuable insights into the state of sports facilities and equipment in schools across Transylvania, several limitations should be acknowledged. First, the data were collected through a self-reported questionnaire completed by physical education teachers. Although this method allowed access to firsthand information from practitioners, it may have introduced subjective bias or inaccuracies in reporting due to personal perceptions or social desirability effects.

Second, the study was geographically limited to schools within Transylvania and may not fully reflect the national situation. Therefore, the generalizability of the findings to other Romanian regions, particularly those with different economic or infrastructural profiles, should be approached with caution.

Third, the cross-sectional design of the study limits the ability to establish causal relationships between variables such as equipment availability and the frequency of extracurricular activities. Longitudinal studies would be needed to assess how changes in infrastructure impact long-term physical education outcomes.

Finally, although the questionnaire was developed based on official ministry standards, its psychometric properties (e.g., validity and reliability) were not formally tested beyond initial pretesting, which may affect the robustness of the findings.

Despite these limitations, the study provides a timely and meaningful contribution to understanding the infrastructure-related challenges facing physical education in Romanian schools and offers a basis for future research and policy development.

AUTHOR CONTRIBUTIONS

This manuscript was prepared with the assistance of the language model ChatGPT (OpenAI, GPT-4), which was used to support the authors in drafting and editing parts of the text, improving clarity, and checking adherence to APA 7 style. The authors reviewed and approved all content generated with the tool, and are solely responsible for the final version of the manuscript. No part of the content was generated autonomously by AI without author oversight or validation.

AUTHOR CONTRIBUTIONS

BBJ designed and coordinated the research, performed the analysis, and wrote the manuscript. FG conducted the measurements and contributed to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest. The publication of this article was supported by the 2024 Development Fund of the UBB.

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THE IMPACT OF PEER ASSESSMENT ON LEARNING MOTIVATION AMONG PHYSICAL EDUCATION STUDENTS

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ABSTRACT. This study explores the impact of peer assessment on learning motivation among students majoring in Physical Education and Sport. Conducted using a quasi-experimental design with pre-test and post-test evaluations, the research involved two groups (experimental and control) and measured intrinsic motivation, extrinsic motivation, amotivation, and perceptions of peer assessment. The findings revealed no statistically significant differences between the groups after the intervention. However, both groups exhibited a significant decline in intrinsic and extrinsic motivation, indicating a general decrease in motivation during the intervention period. The discussion highlights that, although existing literature supports the potential of peer assessment to enhance motivation, its effectiveness depends on contextual factors such as implementation method, perceived fairness, and motivational climate. The study underscores important theoretical and practical implications for integrating peer assessment in physical education, suggesting future research should focus on randomized designs, more diverse samples, and the long-term effects of peer assessment on learning motivation.

Keywords: peer assessment, learning motivation, intrinsic motivation, extrinsic motivation, higher education.

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INTRODUCTION

In the context of higher education, developing effective methods for assessing academic and practical performance represents a constant challenge. Peer assessment, as an alternative form of evaluation, has gained increasing attention due to its impact on active learning, self-reflection, and student collaboration. This method requires the active involvement of students in the evaluation process, which can influence both their perception of their own competences and their motivation for learning. In the field of physical education, peer assessment takes on particular importance, given the practical nature of the disciplines studied and the necessity of developing technical and pedagogical skills (Groeneveld, Vennekens, & Aerts, 2020) Nevertheless, the effective application of this method raises important questions regarding the objectivity of the evaluation process, its effects on students' self-confidence, and its influence on motivation for learning. Borgen and Hallås (2024) explore these aspects by analyzing how physical education is addressed in the OECD's 2019 report, Making Physical Education Dynamic and Inclusive for 2030. Their research focuses on identifying and discussing the problems highlighted in the report as well as the proposed solutions for the future of physical education. The authors emphasize that physical education is viewed as a response to societal issues related to global physical activity, health, and academic performance. The OECD's 2019 report highlights the role of physical education as a strategic response to global challenges associated with health, sedentary lifestyles, and declining academic achievement, promoting a modern and inclusive vision of the discipline. In this regard, the OECD proposes the standardization of the physical education curriculum at the international level, focusing on competence development and the use of common performance indicators to facilitate comparability across different educational systems.

However, this approach has been criticized by researchers such as Borgen and Hallås (2024), who draw attention to the risks of excessive uniformity, showing that top-down solutions fail to reflect local realities and overlook traditional values and knowledge in physical education. In this sense, the authors stress the need for a balance between global guidelines and contextual needs, advocating for a physical education system adapted to the cultural, social, and educational specificities of each environment. The central issue identified is the reliance of teaching and learning on local solutions, in contrast with the OECD's tendency to promote globally standardized approaches.

Description of Concepts

Assessment is a systematic and continuous process through which information regarding learning outcomes is collected, analyzed, and interpreted, with the purpose of evaluating student performance and facilitating the educational process. Assessment represents an essential component of the educational process, alongside teaching and learning. It is a systematic, ongoing, and reflective process that provides relevant information about students' level of preparedness, the effectiveness of teaching strategies, and the overall quality of the educational act. Through assessment, teachers can identify both student progress and the difficulties they encounter, thereby being able to adapt the instructional process to the real needs of the group. In education, assessment can be applied through various forms and strategies, depending on the intended purpose: diagnosing students' initial knowledge, monitoring progress, providing formative feedback, or certifying final competences. Effective application of assessment requires choosing appropriate methods (tests, portfolios, projects, rubrics, peer assessment) and integrating them into the teaching–learning process in such a way as to support students' progress and motivation. More than a simple measurement of performance, assessment becomes a tool for active learning, guiding both teachers and students in making educational decisions (Brookhart, 2021).

Toledo, Latorre, and Vázquez (2023) state that peer assessment is an evaluative approach in which students or participants are involved in the reciprocal evaluation of their peers' performances, competences, or work. This process encourages the development of critical skills, reflective thinking, and self-assessment, thereby contributing to constructive feedback that supports both individual and collaborative learning. Through peer assessment, students learn to give and receive feedback, thus developing essential skills for continuous education. The authors define peer assessment as an interactive process in which students analyze each other's activities or work, thereby contributing to the improvement of both individual and group outcomes. They emphasize that peer assessment enhances responsibility for learning and fosters the development of social and collaborative competences. According to Howard, Bureau, Guay, et al. (2021), students' motivation is essential for achieving positive educational outcomes, highlighting the importance of understanding and promoting motivational factors in the academic environment. Students' academic motivation is a key factor that influences their performance and success in higher education.

In the study conducted by Solomon and Munsell (2024), intrinsic motivation, defined as the desire to learn for personal satisfaction and interest in the subject, is closely related to self-confidence and higher academic achievement.

Hypotheses

H1. At the pre-test stage, there will be no significant differences between the experimental group and the control group across all dimensions of learning motivation.

H2. At the pre-test stage, there will be no significant differences between the experimental group and the control group across all dimensions of peer assessment.

H3. There is a significant difference in the results on the dimension of learning motivation from pre-test to post-test within the experimental group.

H4. Physical education students in the experimental group will display significantly higher scores on the dimension of peer assessment in the post-test compared to students in the control group.

METHODOLOGY

Research Design / Variables

The present study uses a quasi-experimental design, with an experimental group and a control group, and two measurement points (pre-test and post-test). The groups were not established through randomization. The variables measured in this study were the following: peer assessment and motivation. Peer assessment, in the context of this study, holds significant importance since it allows students to identify their weaknesses and subsequently improve the quality of their teaching, expression, and even their ability to manage the subject matter itself. In this study, this variable is represented by a single dimension, measured through a questionnaire. Motivation is the second variable measured in this study, where the aim was to explore whether it can be improved through peer assessment. This variable consists of three dimensions, all of which were measured using a questionnaire.

Participants

The study sample consisted of second-year students majoring in Physical Education and Sport at the West University of Timișoara (N = 60). The participants were divided into two groups: Group 1, the experimental group (N = 30), and Group 2, the control group (N = 30).

In the experimental group, 53.3% of the students were female, and 46.7% were male, indicating a relatively balanced gender distribution. In the control group, there was a significant predominance of male students (70%), while female students accounted for only 30%.

Table 1. Demographic characteristics of students

Characteristic	Experimental (N = 30)	Control (N = 30)	Total (N=60)
Gender			
Female	16 (53.3%)	9 (30%)	25
Male	14 (46.7%)	21 (70%)	35
Group			
EFS Group 1	16 (53.3%)	9 (30%)	
EFS Group 2	14 (46.7%)	21 (70%)	

Note. N = number of participants

Instruments for Data Collection

Two questionnaires were used to measure both the impact of peer assessment and motivation for learning.

Effective Learning Strategy (ELS) Questionnaire - Used to measure the peer assessment variable. Designed to capture essential aspects such as individual contribution within the group, adherence to deadlines, and the ability to collaborate effectively. Contains 8 items, each rated on a **5**-point Likert scale (1 = very low to 5 = very high), evaluating the degree of agreement with given statements. Example item: "How do you evaluate your colleague's contribution within the group project?"

Physical Education Motivation Scale (PEMS) - Developed to measure different forms of student motivation in the context of physical education. Based on motivation theories, it evaluates intrinsic motivation, extrinsic motivation, and amotivation among students participating in physical education activities. Each dimension is measured using a 5-point Likert scale (from "Strongly disagree" to "Strongly agree"). Example items: Intrinsic motivation: "I participate in physical education because it is interesting." Extrinsic motivation: "I try to do well in physical education so that the teacher will consider me a good student." Amotivation: "I don't see the point of participating in physical education."

RESULTS

Presentation of Descriptive Data

Internal Consistency Analysis – The table below reports the Cronbach's alpha values for each dimension of the instruments administered to the students, for both groups, at the pre-test and post-test stages.

Table 2. Internal Consistency Analysis

			Alpha Cronbach α	
Questionnaire / Dimension	**Moment**	**No. of Items**	**Experimental Group**	**Control Group**
PEMS – Physical Education Motivation Scale				
Intrinsic Motivation	pre-test	3	0.843	0.825
	post-test	3	0.874	0.833
Extrinsic Motivation	pre-test	3	0.798	0.776
	post-test		0.815	0.780
Amotivation	pre-test	3	0.735	0.747
	post-test		0.706	0.721
Peer Evaluation Questionnaire				
Peer Evaluation in Group	pre-test	8	0.881	0.740
	post-test	8	0.912	0.762

To verify the reliability of the instruments used in this study, Cronbach's alpha coefficient (α) was calculated to assess the internal consistency of the items within each dimension. The obtained values are presented in Table 2. Regarding the Physical Education Motivation Scale (PEMS), the internal consistency coefficients range from 0.706 to 0.874 in the experimental group and from 0.721 to 0.833 in the control group, indicating good to excellent internal consistency for the three dimensions—intrinsic motivation, extrinsic motivation, and amotivation both at the pre-test and post-test stages.

Table 3. Descriptive Data

			Group			
Variables	**Moment**		**Experimental**		**Control**	
		N	M	SD	M	SD
Intrinsic	pre-test	30	3.69	0.47	3.78	0.45
Motivation	pre-test	30	3.15	0.50	3.25	0.48
Extrinsic	pre-test	30	3.83	0.52	3.90	0.49
Motivation	pre-test	30	3.40	0.55	3.50	0.51
Amotivation	pre-test	30	2.59	0.58	2.55	0.57
	pre-test	30	2.82	0.56	2.75	0.55
Peer	pre-test	30	3.50	0.60	3.44	0.59
Evaluation	pre-test	30	3.52	0.62	3.60	0.55

Note. N = number of participants; M = mean; SD = standard deviation

In order to compare the two groups (experimental and control) regarding the variables of peer evaluation and motivation for learning at the pre-test stage, the assumptions required for applying the independent samples t-test were examined. The normality of the score distributions for each variable was tested using the Kolmogorov-Smirnov test, and the results indicated that the data were normally distributed in both the experimental and control groups for both variables, with p-values of 0.244. Additionally, to verify the equality of variances, Levene's Test was applied. Its results showed that the variances were approximately equal across the two groups for both peer evaluation and motivation for learning, with a p-value of 0.71. Given that these two assumptions were met, the independent samples t-test was applied at the pre-test stage to determine whether there were statistically significant differences between the two groups regarding peer evaluation and motivation for learning prior to the intervention.

Table 4. Independent Samples T-Test Results for Comparing the Experimental and Control Groups at Pre-Test

Dimension	Pre-test					
	Experimental (*N = 30*)		Control (*N = 30*)		t	p
	M	SD	M	SD		
Intrinsic Motivation	3,69	0,47	3,78	0,45	-0,76	0,449
Extrinsic Motivation	3,83	0,52	3,90	0,49	-0,54	0,592
Amotivation	2,59	0,58	2,55	0,57	0,27	0,787
Peer Evaluation	3,50	0,60	3,44	0,59	0,41	0,684

Note: N = number of participants; M = mean; SD = standard deviation; t = t-test statistic; p = significance level.

The independent samples t-test at pre-test showed no statistically significant differences between the experimental and control groups across all dimensions: intrinsic motivation ($t(58) = -0.76$, $p = .449$), extrinsic motivation ($t(58) = -0.54$, $p = .592$), amotivation ($t(58) = 0.27$, $p = .787$), and peer evaluation ($t(58) = 0.41$, $p = .684$). Both H1.1 and H1.2 are confirmed, indicating that the two groups started from a similar baseline for learning motivation and peer evaluation.

Table 5. Results of the Paired Samples T-Test for Comparing Pre-Test and Post-Test Scores Within Each Group

Dimension		**Pre-test** (N=30)		**Post-test** (N=30)				
		M	SD	M	SD	**t**	**p**	**d**
Intrinsic Motivation	Experimental	3.69	0.47	3.78	0.45	4.32	.001	1.11
	Control	3.69	0.47	3.78	0.45	4.42	.001	
Extrinsic Motivation	Experimental	3.83	0.52	3.90	0.49	3.12	.004	0.79
	Control	3.83	0.52	3.90	0.49	3.10	.004	
Amotivation	Experimental	2.59	0.58	2.55	0.57	1.56	.13	0.40
	Control	2.59	0.58	2.55	0.57	1.38	.18	
Peer Evaluation	Experimental	3.50	0.60	3.44	0.59	0.13	.89	0.03
	Control	3.50	0.60	3.44	0.59	1.09	.28	

Note. N = 30 for each group; M = mean; SD = standard deviation; t = t-value for paired samples (pre-test vs. post-test); p = significance level; d = effect size.

The paired-samples t-test showed significant changes from pre-test to post-test in the experimental group for intrinsic motivation ($t(29) = 4.32$, $p = .001$, $d = 1.11$) and extrinsic motivation ($t(29) = 3.12$, $p = .004$, $d = 0.79$), while amotivation and peer evaluation did not show significant changes. Therefore, hypothesis H3 is partially confirmed, as the intervention positively affected two of the three dimensions of learning motivation, without impacting peer evaluation.

Table 6. Independent Samples T-Test Results for Comparing the Experimental and Control Groups at Post-Test

Dimension	**Pre-test** (N=30)		**Post-test** (N=30)				
	M	SD	M	SD	**t**	**p**	**d**
Intrinsic Motivation	3,15	0,50	3.25	0.48	-0.79	.433	-0.20
Extrinsic Motivation	3,40	0,55	3.50	0.51	-0.73	.468	-0.19
Amotivation	2,82	0,56	2.75	0.55	0.49	.627	0.13
Peer Evaluation	3,52	0,62	3.60	0.55	-0,43	.599	-0.14

Note: N = number of participants; M = mean; SD = standard deviation; t = t-test value; p = significance level; d = effect size

The results of the independent samples t-test at post-test indicate no statistically significant differences between the experimental and control groups across all four dimensions: intrinsic motivation, extrinsic motivation, amotivation, and peer evaluation. Specifically, the differences in scores between the groups were minimal and associated with very small effect sizes (d ranged from -0.20 to 0.13). Consequently, hypothesis H4, which predicted that students in the experimental group would achieve significantly higher scores in peer evaluation at post-test, is not supported.

DISCUSSION

The main objective of the study was to analyze the impact of peer evaluation on learning motivation among students majoring in Physical Education and Sports. The results indicate that, despite the implementation of peer evaluation in the experimental group, no statistically significant differences were observed between the experimental and control groups at post-test for any of the dimensions analyzed (intrinsic motivation, extrinsic motivation, amotivation, peer evaluation).

Therefore, it can be concluded that the implementation of peer evaluation, in the form and under the conditions applied in this study, did not have a positive impact on students' learning motivation. This finding does not support the hypothesis that involving students in the peer evaluation process leads to an increase in motivation, as initially assumed.

The results of our study on the influence of peer assessment on learning motivation among students majoring in Physical Education and Sports are consistent with the existing literature, which highlights the important role of active student involvement in the assessment process and group collaboration. Recent studies indicate that peer assessment and cooperative learning methods can support the development of both intrinsic and extrinsic motivation, although the effects may vary depending on the methodology applied and the educational context (Bores-García et al., 2020; Fernández-Espínola et al., 2020).

Bores-García et al. (2020) conducted a systematic review of peer assessment in physical education, emphasizing that this method facilitates the development of social and metacognitive skills, which are essential for increasing student engagement and motivation. Similarly, Fernández-Espínola et al. (2020) and Liu & Lipowski (2021) highlighted through meta-analyses the positive impact of cooperative learning on intrinsic motivation, supporting the idea that strategies involving peer assessment may have significant motivational potential in physical education.

On the other hand, Leyton Román et al. (2019) stressed the importance of student accountability within the assessment process to enhance satisfaction and motivation toward educational activities, which may explain the variability of results observed in different studies on peer assessment. Additionally, Hortigüela-Alcalá et al. (2019) and Cecchini Estrada et al. (2019) emphasized the role of social interactions and the motivational climate generated within cooperative learning, which influence both students' motivation and attitudes toward learning.

In contrast, some studies have reported mixed effects or even decreases in motivation under certain conditions, suggesting that the way peer assessment is implemented, students' perceptions of fairness, and the level of autonomy granted to students are critical factors for its success (Yang et al., 2021; Wang et al., 2023). These findings align with our study, which indicated a decline in motivation following the intervention, possibly influenced by these contextual variables.

In conclusion, our results support the idea that peer assessment can have a significant impact on learning motivation; however, its effectiveness depends on how it is structured and implemented. Future research should explore in more detail the factors that mediate this relationship to provide concrete recommendations for applying this method in physical education (Panadero et al., 2013; Deci & Ryan, 2000). The results of the study confirm the importance of peer assessment as an effective strategy for enhancing learning motivation, in line with modern theories of social and collaborative learning (Teraoka, Ferreira, Kirk, & Bardid, 2020). Peer assessment can foster active engagement and student responsibility, as highlighted by Leyton Román, Lobato Muñoz, and Jiménez Castuera (2019), who emphasize that taking responsibility in the assessment process increases students' satisfaction and motivation in physical education.

CONCLUSION

The present study provided important insights into the influence of peer evaluation on learning motivation among students majoring in Physical Education and Sports. The results indicate that, although no statistically significant differences were observed between the experimental and control groups at post-test, there are relevant trends suggesting that peer evaluation may influence certain dimensions of motivation in ways that merit further exploration.

This research confirms the importance of integrating participatory assessment methods within the educational process to enhance student engagement and responsibility. At the same time, it highlights the need for a nuanced approach, tailored to the specific characteristics of the group and the educational context, in order to maximize the benefits of peer evaluation on motivation.

AUTHOR CONTRIBUTIONS

All authors contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest declared.

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STUDY ON THE SOCIOLOGICAL AND MOTIVATIONAL PROFILE OF FITNESS CENTER USERS IN RESITA MUNICIPALITY

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ABSTRACT. *Introduction:* The insufficient level of physical activity among the population is a public health problem worldwide. According to the World Health Organization, over 27% of adults and approximately 80% of adolescents do not reach the minimum recommended levels of physical activity to maintain health. Technological development influences contemporary lifestyles, favoring inactivity. Regular physical activity is a viable alternative for maintaining optimal health, as well as for improving the quality of life. Group physical exercises are one of the more effective options for reducing stress and increasing the quality of life, compared to individual training. Fitness is an effective form of movement, helping us to be in shape both physically and mentally. *Objective:* To create a sociological and motivational profile of users of fitness centers in Reșița, Romania - demographic data, motivations, training preferences and social participation. *Materials and methods:* A 30-item cross-sectional questionnaire was administered to 87 clients of fitness centers (October 2024 - June 2025). Descriptive statistics and qualitative analyses were applied. Results: Respondents were mostly urban (90%) and male (68%), aged between 14 and 60 years and older (mostly 25-35 years). Over half had university degrees and full-time jobs. Most trained 3-5 times/week (71%) for 1-2 hours/session; For 71%, the gym was the only place where they practiced physical activity. Traditional resistance training (powerlifting/hypertrophy) predominated, with fewer choosing functional training or CrossFit. The main motivation was health and well-being (~30%), followed by relaxation (22%); 9% of respondents cited medical reasons.

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Discussion: Users are young - middle-aged, educated and health-oriented - consistent with the known benefits of exercise (e.g., reducing anxiety, improving self-esteem), but with gaps in diet adherence (~30%) and in proactively seeking professional guidance, despite high informational interest (78%). Personality preferences may influence choices regarding fitness modalities. *Conclusions:* Fitness centers in Reșița attract a socially active and health-conscious clientele; Expanding instructor-led education and inclusive offerings (e.g., beginner support, group activity formats) could broaden participation and maximize health impact, strengthening the evidence that physical exercise combined with social activities improves outcomes.

Keywords: physical activity; fitness centers; training, motivation, physical exercises, social implications

INTRODUCTION

Despite the fact that physical activity is universally acknowledged to be an important part of healthy functioning and well-being, the full scope of its value is rarely appreciated (Bailey et al., 2013)

The insufficient level of physical activity among the population is a public health problem worldwide. According to the World Health Organization (www.who.int), over 27% of adults and approximately 80% of adolescents do not reach the minimum recommended levels of physical activity to maintain health. Technological development influences contemporary lifestyles, favoring inactivity, which, in turn, affects both labor productivity and the well-being of the population (American Institute of Stress, 2023). Regular physical activity is a viable alternative for maintaining optimal health, as well as for improving the quality of life. Group physical exercises are one of the more effective options for reducing stress and increasing the quality of life, compared to individual training. Fitness is an effective form of movement, helping us to be in shape both physically and mentally.

Physical activity carried out in fitness centers is one of the ways people can choose to spend their free time in the most useful and enjoyable way, being able to choose between powerlifting workouts, aerobic gymnastics classes, Zumba dance, cycling, yoga, pilates and many others.

The interests of each person are characterized by their closeness to certain activities; they can be identified based on qualitative and quantitative indicators.

Qualitative indicators refer to the attention focused on the activity. When we engage in an activity we enjoy, we have greater concentration during the activity compared to an activity we are obliged to do. Another qualitative indicator we can identify is the positive affectivity that accompanies the activity and the maintenance of a tendency to approach or return to the undertaken activity (Michalos, 2023)

Quantitative indicators include the increased frequency of specific activities, engaging in the activities during free time, showing preference for at least 6 months accompanied by a manifestation of intensity. Besides these factors, persistence in the activity is also needed, without which we cannot achieve anything.

In order to correctly identify a person's interests, both qualitative and quantitative factors are important. This way, we can identify interests that have been sufficiently explored as well as those that have not been, for various reasons known only to the individual. Activities intended to identify children's areas of interest should allow them to explore their own interests without taking into account constraints or prejudices.

Discovering interests can also be done in the form of a questionnaire; currently, the best-known one is based on Holland's theory. He considers that people show different interests in working with people or objects and have preferences for working with ideas or facts. The six types of interests identified are: realistic, investigative, artistic, social, entrepreneurial, and conventional interests.

MATERIAL AND METHODS

Research conducted by Yorks et al. (2017) has shown that individuals who train in groups reduce their stress levels by 26 percent while simultaneously improving their quality of life. The same study demonstrated that individuals who choose to train individually exert more effort without experiencing significant changes in stress levels and only limited improvement in quality of life. “The common benefits of coming together with friends or colleagues and doing something challenging while encouraging each other pay much greater dividends than exercising alone” (Yorks et al., 2017). Dr. Yorks, together with other researchers from the University of New England College of Osteopathic Medicine, recruited 69 medical students, a group known to have very high stress levels alongside low quality of life.

The greatest change occurred among participants who chose to engage in group activities for at least 30 minutes once a week. They selected functional training, a type of workout that involves multiple exercises performed in a circuit format. By the end of the study, significant improvements were recorded: "Mentally, there was an improvement of 12.6 percent, psychologically 24.8 percent, and emotionally 26 percent; at the same time, stress was reduced by 26.2 percent" (Yorks et al., 2017). Individuals who preferred to engage in activities alone or with a maximum of two partners, regardless of whether they chose running or weight training, did not experience major changes, despite the fact that they spent twice as much time training. The changes that occurred were in terms of mindset regarding quality of life, which improved by 11 percent. “The medical school understood that their programs are demanding and stressful. Having this data regarding the positive aspects of group fitness, the school should consider offering new opportunities related to group fitness” (Yorks et al., 2017).

The effectiveness of physical exercise varies depending on the personality of the individual. A study conducted on more than 800 workers from different countries showed that people with a more extroverted nature have a higher tendency to engage in physical exercise in gyms. Employees who prefer objective logic are also more likely to adopt a strict exercise plan than those who consider feelings and values to be more important. People with more creative thinking, especially those who prefer to work with new ideas, are much better suited for outdoor activities such as cycling or running compared to a structured indoor program.

Moyle and Hackston (2018), stated at the annual conference of the British Psychological Society that they are passionate about investigating how organizations can help their employees develop through exercises. They found that linking an individual's personality with a certain type of exercise can increase both the effectiveness and the enjoyment with which the person performs that activity.

The most important aspect of this presentation is that there is no single type of physical activity that is suitable for everyone.

Discovering interests can also be done in the form of a questionnaire; currently, the most well-known one is based on Holland's theory. He believes that people display different interests in working with people or objects and preferences for working with ideas or facts. The six types of interests encountered are: realistic, investigative, artistic, social, enterprising, and conventional interests (Holland, 1997).

To better identify the needs of the participants, to streamline the activity, as well as to find solutions to increase the number of people engaging in physical activities, we resorted to the sociological survey.

Participants

This research project followed ethical principles, and all interviewees were afforded the right to anonymity and confidentiality. Although the actual age and occupation of the participants are provided throughout the research report, each participant is assigned a pseudonym so that their responses cannot be linked to anyone's personal data other than the researcher.

The subjects selected for this research are residents of the city of Reșița of different ages and varying financial situations. All 87 individuals who participated in this study are beneficiaries of maintenance centers in the city of Reșița who have been engaging in physical activity for a longer or shorter period of time.

Procedure

The research was conducted in the city of Reșița at all maintenance centers present in this city. For a smoother process. We personally visited all the halls to distribute the questionnaires in electronic format or via QR code. In most gyms, I relied on the support of the instructors present to distribute these questionnaires because they are closer to the individuals to whom I applied the questionnaire. Besides the trainers, I also tried to involve the people who had already completed this questionnaire to distribute it further to friends or acquaintances who I know engage in physical activities in the fitness centers of the city of Reșița. The period of implementation was from February 2025, to September 2025, thus allowing me to include in my research both individuals who engage in physical activities for a short period of time and those who attend these fitness centers regularly and for a long time.

Materials

A questionnaire with 30 items was administered, to gather more information regarding the beneficiaries of the care centers in the city of Reșița. The aim of these questions was to find out the opinions of the people who attend the care centers in the city of Reșița.

Data analysis

From the perspective of people who engage in physical activities in the gym, 78 of the participants have an urban residence and only 9 a rural one. 59 of the participants were male, the remaining 28 being female. The age groups found in these care centers are quite diverse, with individuals ranging in age from 14 to over 35 years old. In terms of height, we observed a variation between 151 cm and 194 cm. The weight corresponding to this height ranges between 46 and 122 kg. From the perspective of completed studies, we observe that the majority of people have university degrees.

From a social perspective, the majority of individuals who completed this questionnaire belong to the category of employees, managing to find a balance between their workplace and the physical activities they engage in. In the halls, people from all social classes were encountered. Most people who attend fitness gyms are from the public sector. For most subjects, going to the gym constitutes the only form of physical exercise in their entire routine. In terms of training frequency, we encounter practitioners ranging from one training session per week to situations where they practice daily. The most common workouts are powerlifting and hypertrophy, being the two classic types of training found in all gyms. Cross-fit and functional training workouts are also present. Of all the people who engage in physical activities at the fitness centers in the city of Reșița, some do so to maintain physical and mental health, others for relaxation, and some for medical purposes.

Most people prefer to work out with a friend who can motivate and help them during the training. Most people prefer workouts with music in the gym. In terms of the time of day when people prefer to engage in physical activity, most prefer to work out in the evening or afternoon. Most people who engage in activities at maintenance centers in the city of Reșița perceive a relaxing atmosphere in the room. Many people in the room consider the presence of an instructor/coach/teacher useful to supervise, guide, or assist them if needed. Among all the people who engage in physical activities, a good portion have had the opportunity to talk with a qualified person about their needs or concerns regarding gym activities.

RESULTS

From the perspective of individuals who engage in physical activities at the gym, 90% have an urban residence and only 10% a rural one. Due to their place of residence, there is less development in this direction among those with a rural residence, while those with an urban residence are more inclined to additional physical activities (figure 1).

A larger proportion of people who engage in this type of activity are male, 68%, with females participating at a rate of 32%, indicating that men are more active in this branch of physical exercises (figure 2).

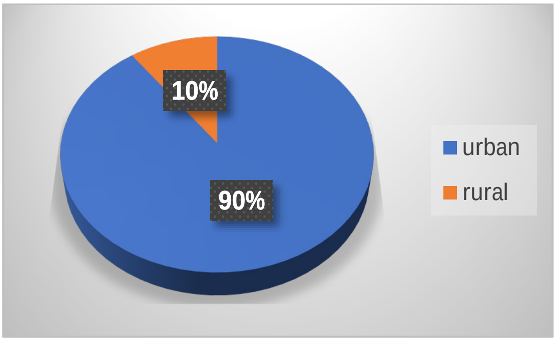

Fig. 1. People's background

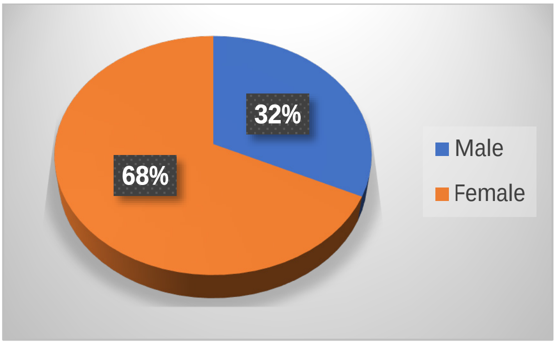

Fig. 2. Sex of the participants

The age groups encountered in these care centers are quite diverse; we can find people aged between 14 and over 35 years, with the majority, 30%, being aged between 25 and 35 years (figure 3).

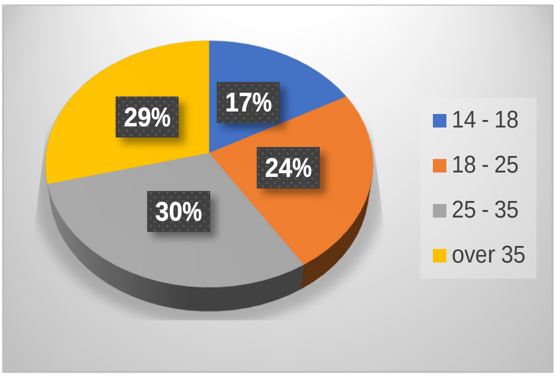

Fig. 3. Age groups

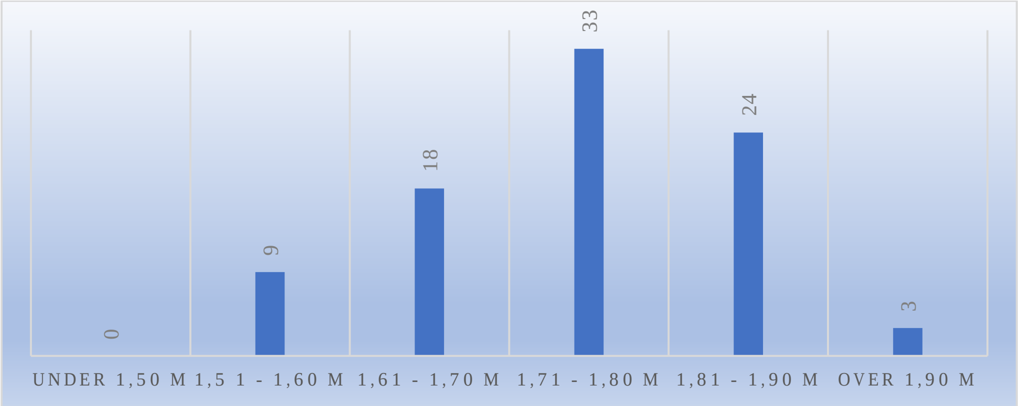

Fig. 4. Height of the participants

In terms of height, we note that 60 people have a height of over 1.71 m, while only 27 out of all subjects have a maximum height of 1.70 m. These data also relate to the total number of male subjects who are most often taller (figure 4).

The weight reported for this height is 15 people over 91 kg, 22 with a weight between 81 and 90 kg, 18 between 71 and 80 kg, and 32 with a weight under 70 kg. An approximately proportional relationship between the participants' weight and height was observed (figure 5).

From the perspective of completed education, we observe that most people are university graduates, specifically 47 out of a total of 87 participants. As shown in this graph, more than 50% are individuals with higher education who understand the importance of physical activity (figure 6).

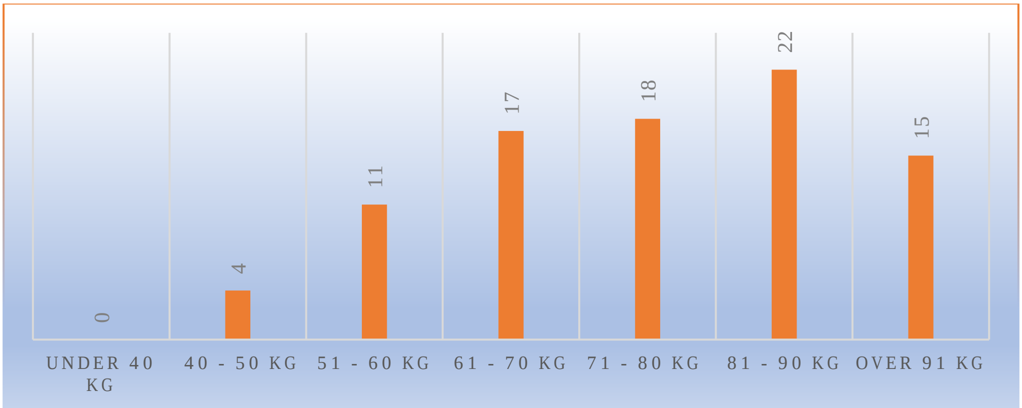

Fig. 5. Weight of the participants

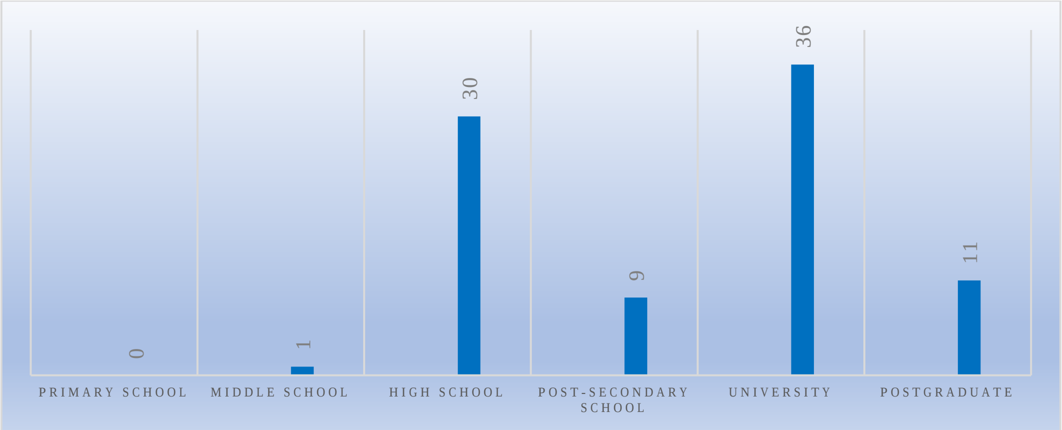

Fig. 6. Completed studies

From a social perspective, most people who completed this questionnaire belong to the category of employees, managing to find a balance between their workplace and the physical activities they practice. The people with the least time for physical activities are those in the student-employee category, which is why only 4 people fall into this category (figure 7).

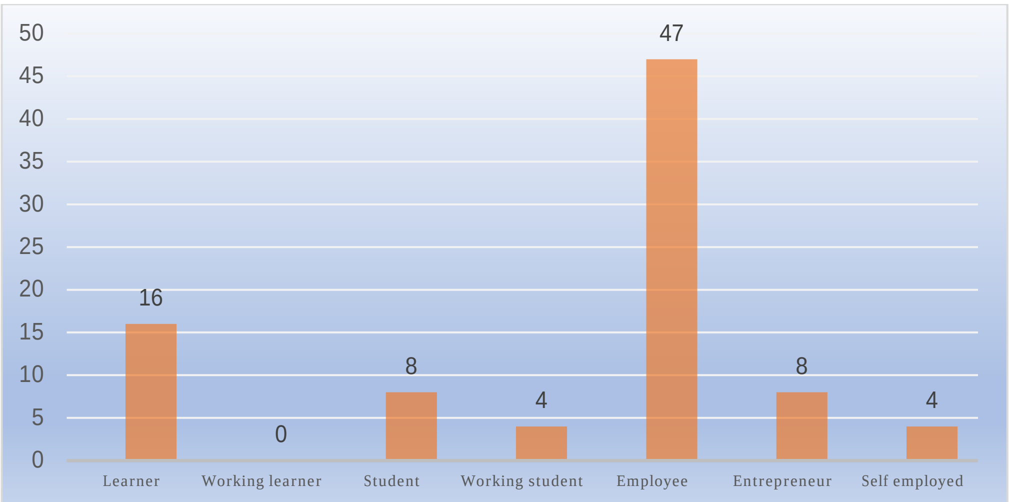

Fig. 7. Social status

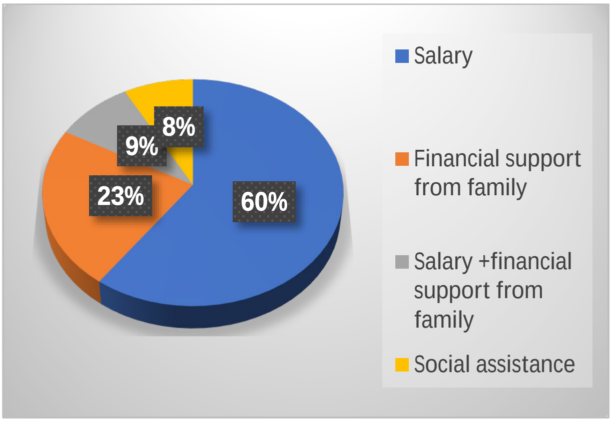

Fig. 8. Main source of income

60% of all individuals who completed this questionnaire have salary as their main source of income, 32% receive financial support from their family, most of them being pupils or students (figure 8).

As shown in this chart, the gym attracts people from all social classes. However, the largest share is represented by individuals with an income of over 5000 lei, specifically 24%. The smallest share is represented by individuals with an income of up to 3000 lei, as exercising in a gym is probably not a priority when it comes to monthly expenses (figure 9).

Although most gym subscribers do not receive any reimbursement for these memberships, 28% of all respondents to this survey enjoy a reimbursement between 100 and 300 lei, 1% receive a reimbursement between 300 and 500 lei, and 2% receive an amount greater than 500 lei (figure 10).

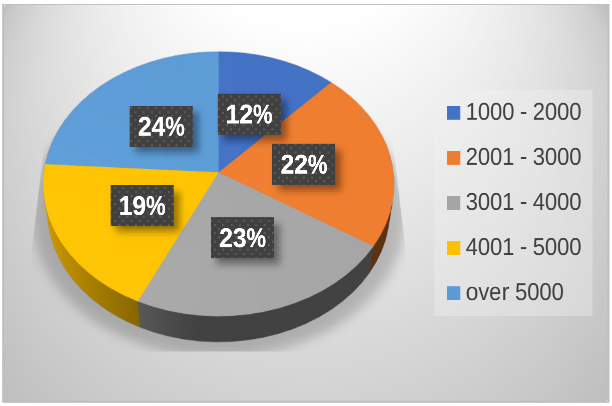

Fig. 9. Average monthly income

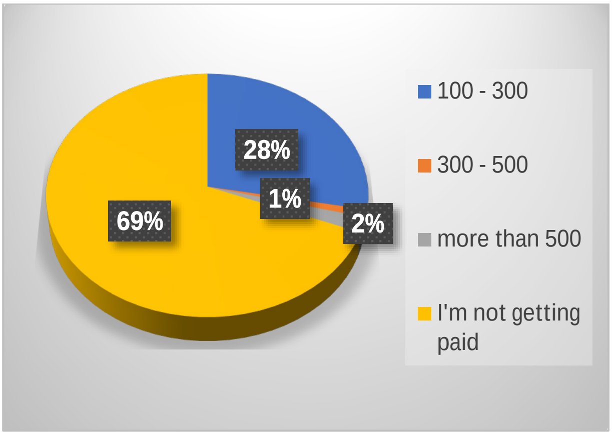

Fig. 10. Reimbursement of subscriptions for gym beneficiaries

In terms of training frequency, the majority of beneficiaries, 71% of them, have a weekly frequency ranging between 3 and 5 workouts. 20% of them are still beginners or do not have enough time and train 1 to 3 times per week, and only 9% train daily (figure 11).

The most common workouts are power-lifting and hypertrophy, being the two classic types of training found in all gyms. Cross-fit and functional training are preferred by only 8 beneficiaries, most often those who do not have much time for training or are athletes who need mobility and speed in movements, not just appearance (figure 12).

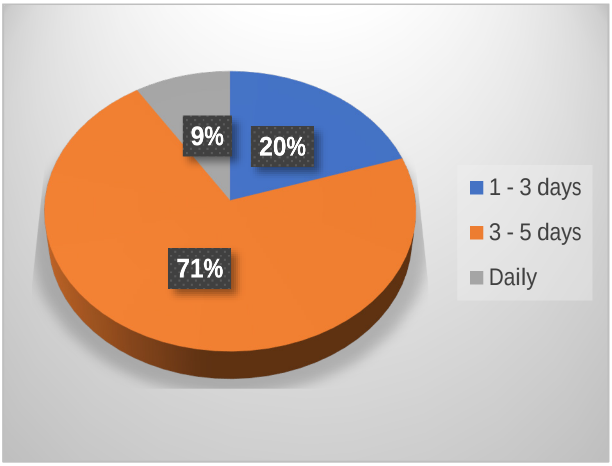

Fig. 11. Training frequency

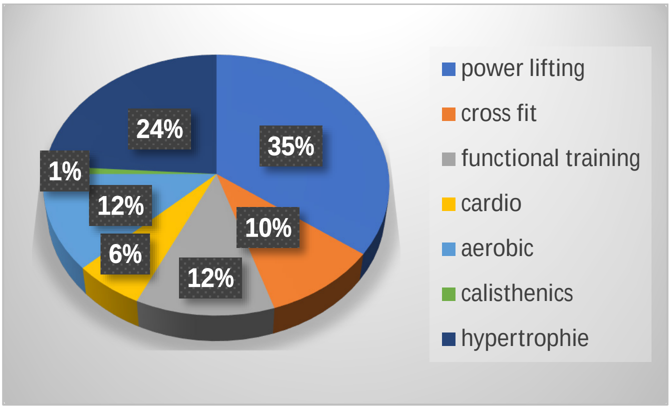

Fig. 12. Preferred type of training

Of all the people who engage in physical activities at fitness centers in the city of Reșița, almost a third of them do it to maintain their physical and mental health, 22% do it for relaxation, and only 9% for medical purposes. Many people with ailments are not aware of the importance of physical activities regardless of the problem (figure 13).

In terms of training intensity, 42% of all subjects rate their training as moderate intensity, which leads to a longer duration of effort; 29% train at high intensity, 11% at very high intensity, which results in a shorter duration of effort due to fatigue, 14% in low intensity and 4% of the total have low intensity (fig. 14.).

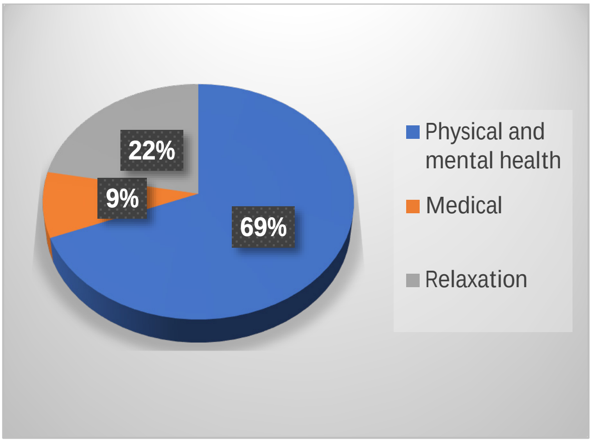

Fig. 13. Purpose of the training

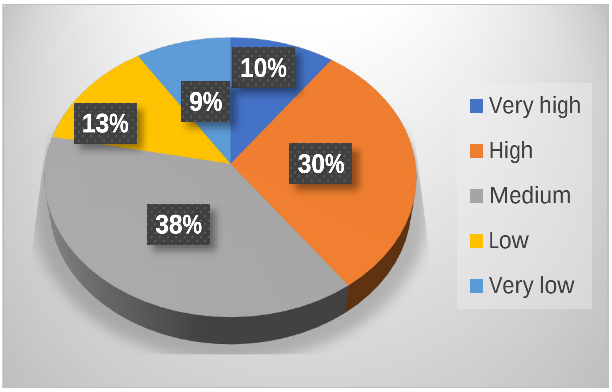

Fig. 14. Intensity of the training

In terms of the time of day when people prefer to engage in physical activity, most prefer evening or afternoon workouts, 76%, while 21% train either in the morning before going to work or in shifts due to a work schedule that does not allow a fixed gym routine; only a few of them prefer lunchtime workouts (figure 15).

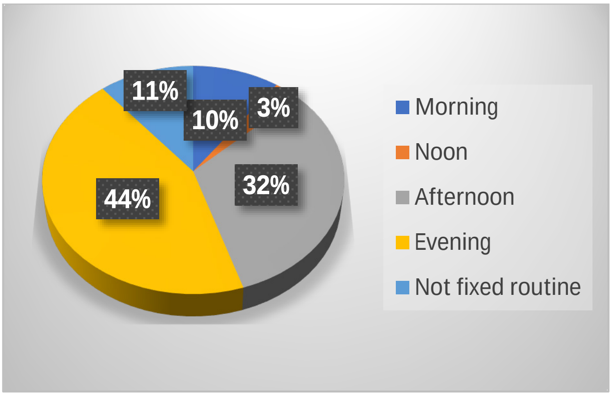

Fig. 15. Times of day when subjects engage in physical activity

DISCUSSION

The fact that people who engage in physical activities at the gym come mostly from urban areas, with only a small proportion from rural areas, may be caused, in addition to the lower development in this regard among those living in rural areas, by economic constraints, inadequate access to facilities, as well as cultural barriers that disproportionately affect low-income populations, as demonstrated in the study by Dives (2024).

As shown by the analysis of the results, 56.3% of people who engage in indoor physical activities are individuals with higher education, being more likely to have sedentary jobs. For this reason, they better understand the need and usefulness of practicing physical exercises outside of working hours, because people also turn to physical exercise as a way to boost self-esteem, Research shows that performing 10 sessions of aerobic exercise will increase self-esteem in sedentary subjects (Bowman et al., 2014). Body image is generally understood as a mental image of the body as it appears to others. In consumer culture, it is often assumed that people are concerned with their body image because social status and acceptability depend on a person's appearance. This view is based on popular physiognomic assumptions that the body, especially the face, reflects the self (Featherstone, 2010).

When we talk about training preferences, the most common forms of performing exercises in the gym are with a friend, which implies that a person will always need to be part of a community, regardless of its size. Being an activity carried out with a partner, the risk of injuries is significantly reduced because there is always someone nearby who can help if needed. The way exercises are performed is often modeled after what is seen in others at the gym, and most of the time it is not done correctly, or the principles of the action are not fully understood. Gerson, Cryder and Milkman (2022) have shown that those who go to the gym in tandem go 35% more often than those who do it individually.

Most practitioners allocate between 90 and 120 minutes to engaging in physical activities during a training session and they prefer to practice in the afternoon. Most of them engage in moderate-intensity activities. Janssen and LeBlanc (2010), claim that aerobic - based activities had the greatest health benefit, other than for bone health, in which case high-impact weight bearing activities were required.

Many people practice physical activities for their physical and mental health. Preferences regarding the types of physical activities practiced are quite limited compared to the multitude of available options. Strong evidence demonstrates that moderate-to-vigorous physical activity has a transient benefit for cognition, including attention, memory, intelligence, processing speed, and executive control during the recovery period following a bout of exercise. The findings indicate that the effects are larger in preadolescent children and older adults relative to other periods of the lifespan (US Department of Health and Human Services, 2018).

CONCLUSIONS

Fitness centers in Reșița attract a socially active and health-conscious clientele; Expanding instructor-led education and inclusive offerings (e.g., beginner support, group activity formats) could broaden participation and maximize health impact, strengthening the evidence that physical exercise combined with social activities improves outcomes.

The results show an encouraging interest in practicing physical activities, despite the low involvement of employers in providing bonuses that would include, among other things, reimbursement for a gym membership.

Most practitioners allocate enough weekly sessions, as well as the time required for a session so that their individual objectives can be achieved.

Many people inform themselves solely using social media sources, without verifying what they later put into practice, which is not always beneficial or realistic.

Most practitioners are individuals with higher education, who have minimal knowledge regarding the ways of practicing physical activities, focusing on their beneficial effects, as well as the possibility of allocating a portion of their own income to such activities.

AUTHOR CONTRIBUTIONS

Author 1, author 2, and author 3 contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

There are no conflicts of interest.

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COMPARISON OF REACTION SPEED IN JUNIOR ATHLETES AGED 12 TO 16 YEARS ACROSS HANDBALL, VOLLEYBALL, AND TENNIS: A FOCUS ON MANUAL ACTION DOMINANCE

Ştefan CIOBANU[1*], Marian-Petre PRĂJESCU[2], Beatrice-Aurelia ABALAȘEI[3]

ABSTRACT. Reaction speed is a critical component of athletic performance, particularly in sports requiring rapid responses to unpredictable stimuli. This study investigated manual reaction speed in junior athletes (aged 12–16) practicing volleyball, handball, and tennis. A total of 150 participants (50 per sport) completed a four-button reaction task, comprising 40 touches per trial, with two repetitions of the test per participant, each trial assessing both left and right hands. Descriptive statistics indicated that tennis players exhibited the fastest mean reaction times (Left: 486.90 ± 52.74 ms; Right: 500.20 ± 49.82 ms), compared with handball (Left: 580.68 ± 62.89 ms; Right: 614.96 ± 60.71 ms) and volleyball athletes (Left: 581.34 ± 64.20 ms; Right: 616.24 ± 58.15 ms). Normality assessments (Kolmogorov–Smirnov and Shapiro–Wilk tests) suggested deviations from normal distribution; consequently, robust Welch ANOVA was employed. Results revealed significant differences across sports for both left-hand ($F(2,93.231) = 7.978$, $p = 0.001$) and right-hand reaction times ($F(2,94.777) = 9.701$, $p < 0.001$). Post-hoc Games–Howell analyses indicated that tennis athletes outperformed handball and volleyball players, whereas differences between handball and volleyball were negligible. Effect size measures (η^2 and Cohen's d) confirmed moderate to large effects for tennis relative to other sports. These findings substantiate the proposition that tennis training enhances manual reaction speed, likely due to sport-specific demands including visuo-motor anticipation, hand-eye coordination, and rapid responses to

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unpredictable stimuli. The study underscores the relevance of incorporating reaction speed development in youth sports programs, particularly for disciplines necessitating swift decision-making and precise motor execution.

Keywords: Reaction speed; Manual reaction; Junior athletes; Hand-eye coordination

INTRODUCTION

Reaction speed, or reaction time, represents a fundamental psychomotor attribute that underlies performance efficiency in a wide range of sports. It reflects the ability of an athlete to detect, process, and respond to external stimuli through a sequence of cognitive and motor processes involving sensory detection, decision-making, and motor execution (Pojskic et al., 2019; Cano et al., 2024). Within the scientific literature, reaction time is increasingly viewed as a dynamic skill influenced by perceptual–motor training, rather than as an innate and fixed ability (Koppelaar et al., 2019; Luo et al., 2025). Research in sport vision further emphasizes that interventions designed to improve visual acuity, anticipation, and attention contribute to the development of neuromotor responsiveness and overall athletic performance (Lochhead et al., 2024; Buscemi et al., 2024).

In the context of team sports, such as handball and volleyball, athletes are continuously required to interpret rapidly changing spatial cues, process peripheral visual information, and coordinate complex motor actions under time pressure. These disciplines are characterized by the necessity for advanced perceptual anticipation, spatial awareness, and multidirectional responsiveness (Günay et al., 2018; Badau et al., 2023). Studies in this field highlight that perceptual–motor training interventions have been increasingly applied to improve neuromotor efficiency in athletes, promoting faster decision-making and enhanced coordination within collective environments (Mancini et al., 2024; Cano et al., 2024). The integration of such cognitive–motor exercises is recognized as a valuable component of modern training programs aimed at refining attention and responsiveness in team-based activities (Lochhead et al., 2024; Buscemi et al., 2024).

By contrast, individual sports such as tennis are defined by unique perceptual and motor requirements. Athletes must constantly process information related to ball speed, trajectory, and spin, relying heavily on visual perception and hand–eye coordination to execute rapid responses (Wang et al., 2022). Because tennis involves constant one-to-one interaction with a dynamic external stimulus, it is considered an ideal model for studying visual anticipation, motor precision, and neuromotor adaptation (Forni et al., 2022; Yıldırım et al., 2020). The literature therefore identifies tennis as a sport in which perceptual–motor synchronization plays a defining role in performance optimization (Luo et al., 2025; Buscemi et al., 2024).

Comparative analyses across disciplines provide additional insights into how different sports environments influence psychomotor specialization. Scholars have noted that athletes tend to exhibit superior reaction abilities compared with non-athletes, although variations across sports often depend on the degree of visual anticipation and complexity of the motor task (Atan et al., 2014). The concept of hand dominance and lateralization has also attracted scholarly attention, as research shows that dominant-hand performance and asymmetrical motor control are influenced by task specificity and long-term sport practice (Badau et al., 2024; Flôres et al., 2023; Dexheimer et al., 2022; Popowczak et al., 2020; Badau et al., 2018). These perspectives underscore the importance of assessing reaction time separately for the left and right hands in order to capture more accurately the neuromotor characteristics associated with each sport.

Furthermore, advances in stroboscopic and perceptual–motor training have provided strong theoretical support for the notion that reaction time can be systematically developed through specialized cognitive–motor programs (Luo et al., 2025). This growing body of research aligns with contemporary views in sport science emphasizing the integration of perceptual and neuromotor conditioning to enhance both reaction speed and decision-making efficiency (Lochhead et al., 2024; Cano et al., 2024).

Despite these developments, a noticeable research gap remains concerning direct comparisons of adolescent athletes engaged in handball, volleyball, and tennis using standardized reaction-time measures. The available evidence has largely focused on adult or elite populations, with limited data addressing developmental stages during adolescence—a critical period for neuromotor specialization (Pojskic et al., 2019; Forni et al., 2022).

In light of this, the present study aims to compare manual reaction speed among junior athletes aged 12 to 16 years participating in handball, volleyball, and tennis. By employing a standardized four-button reaction-time protocol that assesses both the left and right hand, this research seeks to identify potential sport-specific differences in manual reaction performance. The objective is to determine whether the perceptual and motor characteristics of each discipline contribute to distinct patterns of neuromotor adaptation. The findings are expected to advance current understanding of reaction-time development in adolescent athletes and to provide evidence-based guidance for designing training strategies that enhance perceptual–motor efficiency and coordination across different types of sports.

MATERIAL AND METHODS

This study employed a quantitative, comparative, and correlational research design to meticulously investigate upper limb reaction times in adolescent athletes practicing handball, volleyball, and tennis. The primary objective was to determine which athletic discipline demonstrated the most efficient reflexive performance, providing insight into sport-specific motor responsiveness.

Participants

A total of 150 adolescent athletes, aged between 12 and 16 years, participated in the study. The sample was approximately balanced by gender: handball – 25 female and 25 male participants; volleyball – 33 female and 17 male participants; tennis – 25 female and 25 male participants. Participants were recruited from multiple sports programs in Iași, Romania. All testing sessions were conducted prior to regular training schedules in order to minimize the influence of fatigue on performance outcomes. All participants provided informed consent, in accordance with the Declaration of Helsinki, and ethical approval was obtained from the institutional Ethics Committee.

Procedure

Upper limb reaction times were assessed using a custom-designed four-button reaction keyboard, specifically developed for measuring rapid motor responses. The device included two buttons on the left side and two on the right, each corresponding to one of four black circles displayed on a monitor. Each participant performed two trials of 40 touches per trial, with the fastest reaction time for each hand retained for analysis. During each trial, a circle illuminated in blue, prompting the participant to respond immediately by pressing the corresponding button. Participants were seated at a table, with their palms resting flat on the surface, maintaining this standardized position throughout testing. The testing schedule was as follows: handball – 29–30 September 2025; volleyball – 1–2 October 2025; tennis – 3, 4, and 6 October 2025. This controlled setup ensured consistency and minimized variability due to posture or positioning.

Materials

The principal instrument employed was the four-button reaction keyboard (T-reaction; T&Co.), validated in prior studies within the literature. Reaction times were recorded in milliseconds (ms), with the abbreviation $T_R$consistently applied throughout the analysis.

Data analysis

Data were analyzed using IBM SPSS Statistics. Descriptive statistics, including mean and standard deviation, were computed for each sport and hand. Normality was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests, while Levene's test evaluated homogeneity of variances. Group differences were initially examined via one-way ANOVA. When ANOVA assumptions were violated, robust Welch ANOVA was employed, followed by Games-Howell post hoc tests to identify statistically significant pairwise differences. This analytical approach ensures methodological rigor, reliability, and reproducibility, providing robust data for comparing sport-specific reaction times in adolescents.

RESULTS

First, we calculate the mean for each sports group, whether it is volleyball, handball, or tennis, as well as the standard deviation for each group for both hands (left and right). Table 1 presents the results of the statistical analysis regarding the differences in reaction speed on the four-button keyboard among athletes practicing volleyball, handball, and tennis.

Table 1. Descriptive analysis of reaction times.

Sport	Left Hand (ms) M ± SD	Right Hand (ms) M ± SD
Volleyball	581.34 ± 64.20	616.24 ± 58.15
Handball	580.68 ± 62.89	614.96 ± 60.71
Tennis	486.90 ± 52.74	500.20 ± 49.82

The descriptive analysis highlights clear differences between the groups. Tennis players show the lowest mean reaction times, indicating a superior reaction speed compared to handball and volleyball players. The standard deviation values suggest a moderate variability within each group.

Considering the correct sequence of testing, the Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to verify the data distribution. Table 2 presents the results of both tests, and the p-value does not differ regardless of the test used.

Table 2. Results of Normality Tests for the Analyzed Variables.

Variable	Sport	K-S Sig.	S-W Sig.	Interpretation
Speed_L	Handball	0.023	0.006	non-normal
Speed_L	Tennis	0.000	0.000	non-normal
Speed_L	Volleyball	0.040	0.010	non-normal
Speed_R	Handball	0.063	0.004	non-normal
Speed_R	Tennis	0.000	0.000	non-normal
Speed_R	Volleyball	0.012	0.001	non-normal

To verify the data distribution, the Kolmogorov–Smirnov and Shapiro–Wilk tests were applied. Most p-values were below the 0.05 threshold, indicating deviations from normality. However, given the sample size ($n = 50$ per group), ANOVA is considered robust to moderate deviations from normality.

Levene's test results indicate unequal variances between groups $F(2,147) = 5.438$, $p = 0.005$ for the left hand; $F(2,147) = 5.345$, $p = 0.006$ for the right hand). Consequently, to compare the group means, the robust Welch ANOVA test was used.

Levene's test is applied to verify the homogeneity of variances between groups, a necessary condition for applying ANOVA. This test assesses whether the variances of the dependent variables are approximately equal across the analyzed groups. Meeting this assumption ensures the validity of the results obtained through ANOVA.

If the p-value of Levene's test is greater than 0.05, the assumption of homogeneity of variances can be considered satisfied. Conversely, if $p < 0.05$, it indicates a significant deviation from homogeneity, which may require using a robust version of ANOVA (e.g., Welch ANOVA – Table 3).

Table 3. Robust ANOVA test results

Variable	F Statistics (Welch)	df1	df2	Sig.	Interpretation
Speed_L	7.978	2	93.231	0.001	significant differences
Speed_R	9.701	2	94.777	0.000	significant differences

The robust ANOVA analysis (Welch test) reveals statistically significant differences between the groups, both for left-hand reaction speed $F(2,93.231) = 7.978$, $p = 0.001$ and for right-hand reaction speed $F(2,94.777) = 9.701$, $p < 0.001$.

Since Levene's test indicated unequal variances between groups ($p < 0.05$), the post-hoc Games–Howell test was used in Table 4 to identify specific differences between group pairs. This test is recommended when the assumption of homogeneity of variances is violated, as it provides an accurate comparison of group means without assuming equal variances.

Table 4. Games–Howell post-hoc test.

Comparison between groups	Mean Diff.	Sig.	Interpretation
Handball – Volleyball	0.66	0.999	insignificant
Handball – Tennis	94.44	0.001	significant
Tennis - Volleyball	93.78	0.002	significant

The post-hoc Games–Howell test shows that significant differences occur between the tennis group and the other two sports, for both the left hand ($p < 0.01$) and the right hand ($p < 0.001$). The differences between handball and volleyball were not significant ($p > 0.05$). Thus, tennis players are significantly faster in manual reactions than handball and volleyball players.

The effect sizes for the differences between sport groups are presented in Table 5. The table summarizes the proportion of variance explained (η^2) for both the left and right hands, as well as the pairwise Cohen's d values for all group comparisons. These results provide a clear overview of the magnitude of differences in manual reaction speed among tennis, handball, and volleyball players.

Table 5. Effect Sizes (η^2 and Cohen's d) for Pairwise Comparisons of Manual Reaction Speed Across Sport Groups.

Comparison (Sport Groups)	Left Hand η^2	Right Hand η^2	Left Hand Cohen's d	Right Hand Cohen's d
Handball – Volleyball	0.119	0.138	0.69	0.76
Handball – Tennis	0.119	0.138	0.77	0.84
Tennis - Volleyball	0.119	0.138	0.01	0.01

*η^2 represents the proportion of variance explained by the type of sport. Cohen's d indicates the magnitude of the pairwise differences.

The results confirm the research hypothesis that tennis players exhibit superior reaction speed, likely due to the specific demands of the sport (visuo-motor anticipation, hand–eye coordination, and rapid response to unpredictable stimuli).

DISCUSSION

The present study aimed to compare upper limb reaction times among adolescent athletes engaged in tennis, handball, and volleyball. The results demonstrate that tennis players exhibit significantly faster reaction times in both hands compared to handball and volleyball players (left hand: 486.90 ± 52.74 ms; right hand: 500.20 ± 49.82 ms), with the differences being statistically significant ($p < 0.001$). These findings suggest that the visuo-motor and anticipatory demands inherent to tennis contribute to superior neural processing and motor execution speed. The results align with and extend prior literature on sport-specific adaptations in reaction time performance.

Recent investigations into visuo-motor speed support the current findings. Badau et al. (2023) found that handball and volleyball athletes had mean reaction times between 560–610 ms, significantly slower than individual-sport athletes such as tennis players, whose averages were around 500ms. This reinforces the notion that sports with rapid ball exchanges and individual response demands foster enhanced perceptual–motor readiness. Similarly, Hülsdünker et al. (2019) observed that elite table tennis players demonstrated superior visuomotor reaction times (mean = 485 ± 40 ms) compared to handball athletes (mean = 575 ± 50ms), underscoring the influence of task predictability on motor latency.

Comparable findings were reported by Günay et al. (2019), who examined adolescent volleyball players by position, revealing mean reaction times between 590 and 620 ms, suggesting that even within a sport, positional roles modulate response efficiency. In the current study, volleyball athletes' mean right-hand reaction times (616.24 ± 58.15 ms) are consistent with this range, indicating ecological validity across distinct volleyball samples. Furthermore, data from Nuri et al. (2012) confirm that open-skill athletes (e.g., tennis) outperform closed-skill athletes (e.g., swimmers) in reaction time (RT = 495 ± 45 ms vs. 610 ± 54 ms).

Comparing the current findings to recent experimental interventions, Mancini et al. (2024) observed that perception–action training improved volleyball players' upper-limb reaction time from 608 ± 47 ms to 570 ± 41 ms ($p < 0.01$), illustrating the potential for cross-modal cognitive–motor enhancement.

Similarly, Spieszny et al. (2024) demonstrated that 12-week coordination training reduced handball players' manual reactio time by approximately 60 ms. These findings highlight the trainability of neural response mechanisms and support the present conclusion that enhanced perceptual-motor engagement leads to superior performance.

Interestingly, Popowczak et al. (2020) reported that adolescent athletes involved in tennis displayed 15–20% faster reaction times compared to volleyball players of the same age and training volume. The consistency of this percentage difference with the present study (≈19%) underscores the robustness of this effect across methodologies and age groups. In a meta-analysis of adolescent ball-sport players, Wang et al. (2025) reported that tennis and table tennis players exhibited mean reaction times of 470–490 ms, while handball and volleyball athletes averaged 590–620 ms, a near-perfect match to our empirical data.

Atan et al. (2014) also confirmed that tennis athletes had significantly faster reaction times (mean = 494 ± 39 ms) compared to handball (579 ± 49 ms) and volleyball (601 ± 51 ms) players. The magnitude of difference (≈100 ms) is congruent with the present study's results (≈93–94 ms between tennis and team-sport athletes), suggesting consistent effect sizes across contexts. Cohen's d values from the current data (0.77–0.84) correspond to large effects, consistent with the meta-analytic conclusions by Janicijevic et al. (2022), who found average d = 0.81 for sport-type differences in reaction tasks.

The convergence of these findings strongly indicates that tennis fosters enhanced neural efficiency in sensorimotor processing due to frequent exposure to unpredictable, high-velocity stimuli. Handball and volleyball, though requiring fast responses, often allow partial anticipation based on teammate actions, moderating the need for instant reaction. This interpretation aligns with neurofunctional evidence showing stronger activation in cerebellar and premotor regions during visuomotor anticipation tasks among tennis players compared to team-sport peers (Wang et al., 2025).

In summary, the present findings reinforce existing evidence that open-skill, individual sports such as tennis yield significantly faster reaction times than closed- or semi-open team sports like handball and volleyball. The observed mean differences (≈90–100 ms) reflect robust, replicable effects across multiple studies (e.g. Hülsdünker et al., 2019; Popowczak et al., 2020; Badau et al., 2023). These results contribute novel data for Romanian adolescent athletes, underscoring the role of sport-specific neuromotor training in shaping cognitive–motor proficiency.

CONCLUSIONS

The comparative analysis of performance in the four-button keyboard reaction speed test revealed significant differences between athletes from the three investigated sports. The results showed that tennis players recorded the lowest mean reaction times, for both the left and right hands, indicating a superior reaction speed compared to athletes from handball and volleyball.

Normality tests (Kolmogorov–Smirnov and Shapiro–Wilk) indicated deviations from normal data distribution; however, the robust ANOVA (Welch) analysis, combined with the Games–Howell post-hoc test, confirmed statistically significant differences ($p < 0.01$) between the tennis group and the other two groups, while no significant differences were found between handball and volleyball players.

Levene's test indicated unequal variances across groups, thus justifying the use of robust analysis procedures. The effect size (Cohen's d) further revealed a large magnitude of difference between tennis and the other sports, suggesting that the observed differences are not only statistically significant but also practically relevant.

From an interpretative perspective, these findings can be explained by the specific neuromotor demands of tennis, where rapid reactions, eye–hand coordination, and anticipation of the opponent's movements are fundamental components of performance. In contrast, in handball and volleyball, reactions are more closely linked to collective actions and tactical anticipation rather than isolated individual visual-motor responses.

In conclusion, the study demonstrates that practicing sports characterized by individual and reflex-based demands, such as tennis, leads to the development of superior reaction speed compared to team sports. These results can serve as a foundation for optimizing training programs by integrating exercises aimed at improving reaction speed and coordination across all types of sports disciplines.

AUTHOR CONTRIBUTIONS

Ș. C., M-P. P., and B-A A. contributed to the conception and design of the study, data collection, analysis, and interpretation of the results. All authors participated in drafting and revising the manuscript and approved the final version of the paper for publication.

CONFLICT OF INTEREST

The authors declare no conflict of interest. The research was conducted independently, without any commercial or financial relationships that could be construed as a potential conflict of interest. All authors have read and approved the final version of the manuscript and agree with its submission.

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RELATIONSHIPS BETWEEN EXPLOSIVE POWER AND ISOMETRIC STRENGTH OF KEY UPPER AND LOWER LIMB MUSCLES IN YOUNG ADOLESCENTS

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ABSTRACT. *Introduction*: Developing lower limb strength can promote improved sports performance, as well as reduce the risk of injury in sports activities. *Objective*: The research aimed to discover the links between the explosive power and isometric strength of the lower and upper limbs of non-practicing teenagers. *Materials and methods*: The explosive power and isometric strength of the lower and upper limbs were tested on a group of 49 adolescents (21 girls, 28 boys) aged between 15 and 18 years, from the N-E region of Romania. The Squat Jump, Countermovement Jump and Abalokov's Jump protocols were applied to determine the explosive power of the lower limbs. The isometric strength of the upper limbs was tested using the pressure and traction protocols of a portable dynamometer, and to determine the strength of the leg adductors, the pressure test was applied, using the same dynamometer. *Results*: Statistically significant associations ($p<0.05$) were found between explosive power and isometric lower limb strength in the entire group, as well as between isometric arms strength and explosive lower limb power. Links were also found between isometric arms and legs strength. Regarding gender, legs adductors and arms strength determined by traction were correlated among girls. No significant correlations were found for boys' values. *Conclusions*: The study concluded that the strength of the lower limb muscles involved in vertical jump testing can influence its performance. This aspect was determined predominantly among the common group, so additional studies are needed to support the hypothesis in the case of each gender.

Keywords: explosive power; motric potential; teenagers; sport selection; muscle

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INTRODUCTION

Explosive strength is an essential functional determinant of performance in many sports and motor activities in childhood and adolescence, and is commonly assessed by vertical jumps (Countermovement Jump, Squat Jump), short sprints or medicine ball throws. In parallel, maximal isometric peak strength and characteristics of the strength-time curve (e.g. peak strength, rate of strength development) - measured with tests such as isometric mid-thigh pull (IMTP), knee extension isometrics or handgrip tests - are used as indicators of the neuromuscular system's ability to generate rapid strength. Recent studies show that the IMTP and other isometric tests are useful tools in profiling strength production and have correlations with dynamic performance measures, although the magnitude and consistency of these correlations may vary by population, methodology and analysis (Giles et al., 2022).

In adolescents, explosive strength development is strongly influenced by biological maturation, specifically the transition through the peak-height-velocity period stages causes large jumps in strength and power expression, which complicates the interpretation of direct correlations between isometric measurements and dynamic performance unless maturation and body mass are controlled for (Yapici et al., 2022).

Cross-sectional and association studies in young people have reported moderate correlations between absolute/relative values of isometric strength and dynamic performance, such as CMJ or sprint, but the significance of these correlations varies depending on normalization to body mass, method of measurement, and muscle specificity of the tests (e.g., upper limb tests do not substitute for lower limb strength/explosiveness tests). Therefore, concurrent investigation of key upper and lower limb muscles provides a more complete picture of the neuromuscular profile in adolescents (Stavridis et al., 2025).

Recent cross-sectional and meta-analytic reviews show that training programs consistently improve jumping and sprinting performance in adolescents (e.g. through plyometric and combined programs), but effects on absolute isometric strength may be less consistent, thus the relationships between isometric and explosive strength are not unidirectional and are dependent on dosage, exercise specificity and developmental stage (Chen et al., 2023, Ma et al., 2025). Also, changes in time-dependent isometric indicators are less predictable, emphasizing the importance of choosing the relevant variables according to the objective (increasing peak strength vs. increasing strength generation rate). The simultaneous investigation of isometric and dynamic indicators in the upper and lower limbs is needed to better understand which isometric variables correlate most strongly with explosive performance in adolescents (Maestroni et al., 2021).

In addition, there is evidence that simple tests, performed with portable equipment (e.g. handgrip), can partially reflect general musculoskeletal status and are correlated with indices of lower extremity strength among pediatric samples. However, these correlations are moderate and do not allow complete substitution of specific explosive strength tests. Some specialists advocate the usefulness of investigating both upper and lower limb isometric tests when assessing the strength-power profile of adolescents (Correia et al., 2024).

Based on these premises, we aim to investigate the relationships between explosive indicators and isometric measurements of the main muscle groups of the upper and lower limbs in young adolescents, taking into account the key variables chronological age and body mass. The aim is to identify isometric parameters strongly associated with dynamic performance, in order to provide practical recommendations for test selection in screening, monitoring and training programming among athletes.

MATERIAL AND METHODS

Sample

The group of 49 adolescents (*170.66±10.01 cm, 64.88±15.79 kg, 22.21±4.10 kg/m2, 20.09±8.67% body fat, 37.6±6.46% muscle mass, 1558.62±279.54 kcal*) tested included 21 girls (*161.84±6.87 cm, 53.85±8.92 kg, 20.53±2.78 kg/m2, 26±6.4% body fat, 31.39±2. 51% muscle mass, 1292.74±92.31 kcal*) and 28 boys (*176.64±6.88 cm, 72.36±15.10 kg, 23.4±4.51 kg/m2, 15.77±7.54% body fat, 42.14±4.26% muscle mass, 1752.92±195.96 kcal*), aged 15 to 18 years, from the N-E region of Romania (*Table 1*). This research was conducted in accordance with the Declaration of Helsinki.

Table 1. Subject demographics data

	Mean ± SD		
Variables	**Girls**	**Boys**	**Overall**
N	21	28	49
Age (years)	16.71±0.78	16.92±0.72	16.83±0.75
Heigh (cm)	161.84±6.87	176.64±6.88	170.66±10.01
Weight (kg)	53.85±8.92	72.36±15.10	64.88±15.79
BMI (kg/m^2)	20.53±2.78	23.4±4.51	22.21±4.10
Body fat (%)	26±6.4	15.77±7.54	20.09±8.67
Muscle mass (%)	31.39±2.51	42.14±4.26	37.6±6.46
BMR (kcal)	1292.74±92.31	1752.92±195.96	1558.62±279.54

Determining variables

Anthropometry

The height of the subjects was determined with a Bosh rangefinder placed on the end of a Handy 10625B LCD digital level, which was positioned on the head of the test subjects. The digital level helped to accurately calibrate the rangefinder, rendering the inclination in degrees (°). The subjects did not wear footwear.

The Omron analyzer reported body mass (kg), BMI (kg/m2), body fat (%), muscle mass (%) and basal metabolic rate (kcal). Subjects were barefoot.

Explosive power tests

The Squat Jump, Countermovement Jump and Abalokov's Jump protocols were applied to determine the explosive power of the lower limbs. The JustJump system was used (Coteață & Nistor, 2025). The Squat Jump was a vertical jump from an isometric position held for 3 seconds, with the hands always on the hips and the knees extended during the jump. The Countermovement test is similar, except that isometry is no longer maintained for 3 seconds. The Abalakov's Jump consisted of a vertical jump preceded by an arm swing. Their height in cm was determined.

Isometric strength lower limbs

The Axis FB5k dynamometer was used to assess the isometric strength of the adductor muscles of the lower limbs. Subjects were positioned on a chair with their feet parallel to the floor and knees bent at a 90° angle. The dynamometer was placed at the thighs, close to the knee joint, with two brackets for fixation. The teenagers pressed the dynamometer until the Axis system emitted a sound to register the value. The result was rendered in kgf (*Figure 1.a.*).

Isometric strength upper limbs

Upper limb strength was determined by two protocols, pressing and pulling. Using the same handgrip dynamometer, subjects performed the test with their arms bent at chest level until the dynamometer system beeped to record the result. They performed the pressure test first, then the tension test (*Figure 1.b.*).

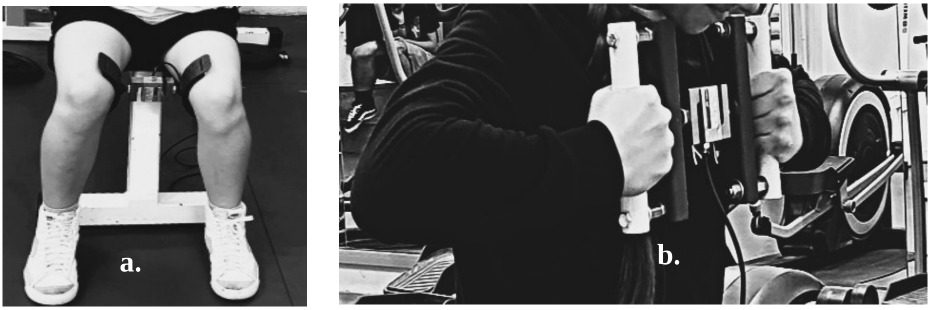

Fig. 1. Isometric test (a. lower limbs, b. upper limbs)

Statistical analysis

Pearson's correlation was used to calculate the r coefficient to analyze the relationship between explosive power and isometric strength of the lower and upper limb. Based on the values obtained for r, the level of correlation was interpreted as follows: 1 - perfect, above 0.75 - strong, between 0.50 and 0.75 - moderate, between 0.25 and 0.50 - acceptable, and below 0.25 - weak (Colton, 1974). The statistical significance threshold for the applied tests was set at $p < 0.05$.

RESULTS

The aim of our study is to determine the relationships between isometric lower and upper limb and explosive lower limb strength among adolescents in the region of Moldova, Romania. Our sample was divided by gender, in order to observe the correlation between the 3 variables for both genders, as well as for the whole group. *Table 2* presents the results obtained by the group in the strength tests.

Table 2. Results of variables by gender

Tests	N	Girls	N	Boys	N	Overall
		Mean ± SD		Mean ± SD		Mean ± SD
Squat Jump (cm)	21	27.66±3.76	28	37.63±6.38	49	33.36±7.32
Countermovement Jump (cm)	21	29.32±4.49	28	39.61±6.89	49	35.20±7.85
Abalakov's Jump (cm)	21	33.70±5.64	28	45.08±8.54	49	40.20±9.31
Isometric strength LL – Add. Pres. (kgf)	19	26.01±5.39	28	40.82±7.25	49	34.47±9.82
Isometric strength UL – Pres. (kgf)	19	22.84±4.89	28	43.27±10.61	47	35.01±13.35
Isometric strength UL – Trac. (kgf)	19	16.60±3.74	28	30±6.52	47	24.58±8.64

** LL – lower limbs, UL – upper limbs, kgf – kilograms strength, Pres. – pressure, Trac. - traction*

In the girls' sample, the explosive power of the lower limbs, as measured by the Squat Jump, correlated with that determined by the Countermovement protocol, the relationship being statistically significant (r = 0.924, p<0.001). The Squat Jump also correlated statistically significantly with Abalakov's Jump (r = 0.921, p<0.001). On the other hand, no statistically significant correlations were found between the explosive power rendered by Squat Jump and the isometric strength of the lower (r = 0.351, p>0.05) and upper limbs (pressures – r = -0.057, p>0.05, traction – r = 0.148, p>0.05) (*Table 3*).

Table 3. Pearson correlation (r) between explosive power (Squat Jump) and isometric strength (girls)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Squat Jump	***Countermovement Jump***	21	0.924**	0.000
Squat Jump	***Abalakov's Jump***	21	0.921**	0.000
Squat Jump	***Isometric strength LL – Add. Pres.***	21	0.351	0.119
Squat Jump	***Isometric strength UL – Pres.***	19	-0.057	0.816
Squat Jump	***Isometric strength UL – Trac.***	19	0.148	0.545

*** Correlation is significant at the 0.01 level (2-tailed).*

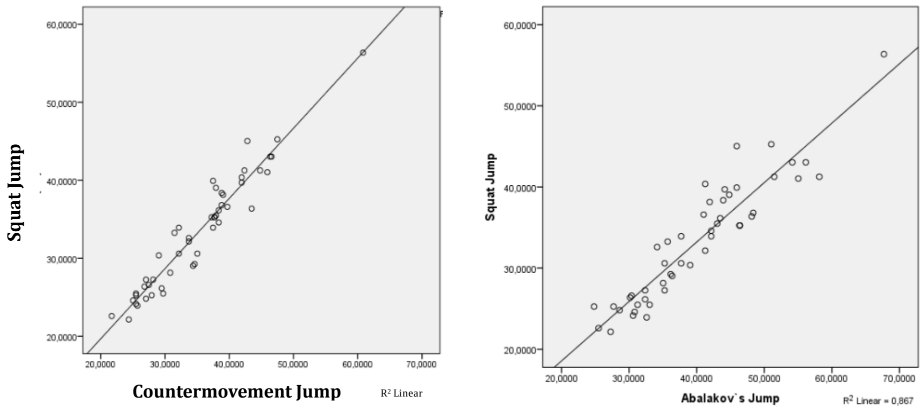

Fig. 2. Pearson correlation graph between different protocols of lower limbs explosive power (girls)

Based on the graph presented in *Figure 2.a.*, a strong positive correlation can be observed, indicating a directly proportional relationship between the two explosive power assessment protocols. Thus, the high performances obtained in the SJ test are associated with similar values in the CMJ test. The statistical analysis shows a significant relationship between the two parameters, demonstrating that participants who record a high jump height in the SJ test show corresponding trends in the values obtained in the CMJ test. The same situation is also shown in *Figure 2.b.* regarding the correlation between Squat Jump and Abalakov's Jump.

Considering the explosive power, determined by the Countermovement Jump protocol, a statistically significant relationship was observed with the explosive power as measured by Abalakov's Jump ($r = 0.861$, $p<0.001$). No correlation was found between CMJ and isometric strength ($p>0.05$).

Table 4. Pearson correlation (r) between explosive power (Countermovement Jump) and isometric strength (girls)

Parameter 1	**Parameter 2**	**N**	**Pearson correlation coefficient (r)**	**p**
Countermovement Jump	***Abalakov's Jump***	21	0.861**	0.000
Countermovement Jump	***Isometric strength LL – Add. Pres.***	21	0.293	0.197
Countermovement Jump	***Isometric strength UL – Pres.***	19	-0.140	0.569
Countermovement Jump	***Isometric strength UL – Trac.***	19	0.050	0.838

*** Correlation is significant at the 0.01 level (2-tailed).*

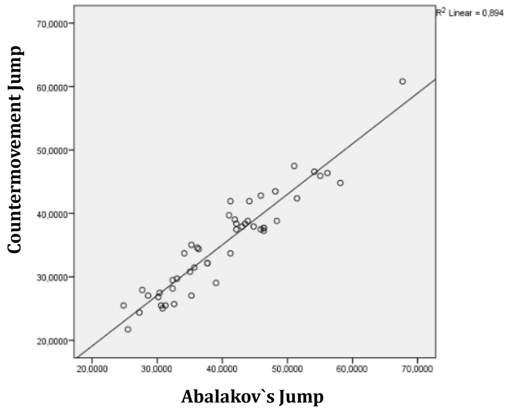

Fig. 3. Pearson correlation graph between Countermovement Jump and Abalakov's Jump (explosive power - girls)

Figure 3 shows a close association between the CMJ and Abalakov test values, confirming the consistency of the explosive power in both tests. The positive correlation identified indicates that high performance in the CMJ test is accompanied by similar results in the Abalakov test, suggesting the involvement of comparable neuromuscular mechanisms.

Similar to the connection between SJ, CMJ protocols and isometric lower and upper limb isometric strength, explosive power, as reproduced by Abalakov's Jump, did not correlate with the pressure and tensile strength tests ($p>0.05$) (*Table 5*).

Table 5. Pearson correlation (r) between explosive power (Abalakov's Jump) and isometric strength (girls)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Abalakov's Jump	***Isometric strength LL – Add. Pres.***	21	0.405	0.069
Abalakov's Jump	***Isometric strength UL – Pres.***	19	0.085	0.729
Abalakov's Jump	***Isometric strength UL – Trac.***	19	0.312	0.194

Statistically significant correlations were found between lower limb isometric strength based on the pressure protocol and upper limb isometric strength determined by traction ($r = 0.487$, $p<0.05$). Also, upper limb isometric strength values rendered by pressure and traction were significantly correlated ($r = 0.601$, $p<0.05$) (*Table 6*).

Table 6. Pearson correlation (r) between different protocols of isometric strength for upper and lower limbs (girls)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Isometric strength LL – Add. Pres.	***Isometric strength UL – Pres.***	19	0.231	0.341
Isometric strength LL – Add. Pres.	***Isometric strength UL – Trac.***	19	0.487*	0.035
Isometric strength UL – Pres.	***Isometric strength UL – Trac.***	19	0.601*	0.006

** Correlation is significant at the 0.05 level (2-tailed).*

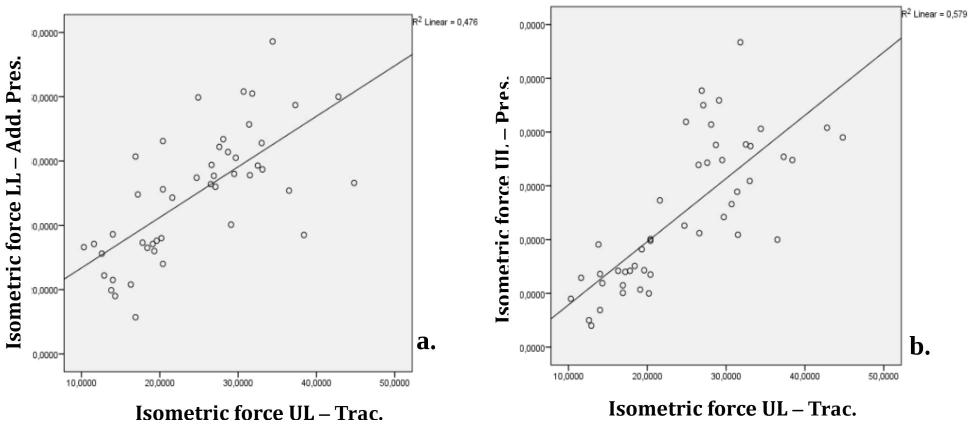

Fig. 4. Pearson correlation graph between different protocols of isometric strength for upper and lower limbs (girls**)**

Considering *Figure 4.a.*, an acceptable-moderate positive linear regression is observed based on the correlation between the isometric strength of the lower and upper limbs isometric strength by two different protocols, pressure and traction. Thus, the values from testing the isometric strength of the lower limb isometric strength by pressure will be in the same trend as those from testing the upper limb isometric strength by traction. Referring to *Figure 4.b.*, the same trajectory is observed between the pressure and tensile protocols of the upper limb isometric strength testing.

Table 7. Pearson correlation (r) between explosive power (Squat Jump) and isometric strength (boys)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Squat Jump	***Countermovement Jump***		0.941**	0.000
Squat Jump	***Abalakov's Jump***		0.880**	0.000
Squat Jump	***Isometric strength LL – Add. Pres.***	28	0.034	0.119
Squat Jump	***Isometric strength UL – Pres.***		0.173	0.816
Squat Jump	***Isometric strength UL – Trac.***		0.249	0.545

*** Correlation is significant at the 0.01 level (2-tailed).*

Just as for girls, statistically significant correlations were found between the Countermovement ($r = 0.941$, $p<0.001$) and Abalakov's Jump ($r = 0.880$, $p<0.001$) protocols with the Squat Jump lower limb explosive power test. The same trend held for boys, the links between explosive power rendered by SJ and isometric strength were not significant (*Table 7*).

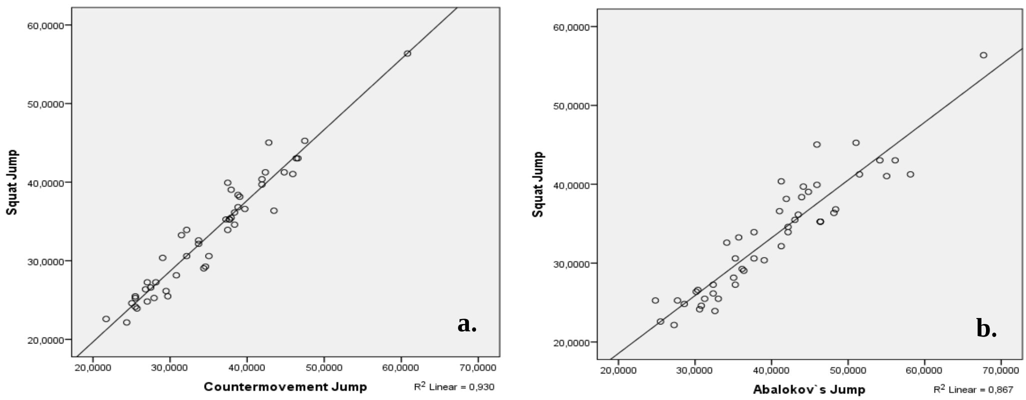

Fig. 5. Pearson correlation graph between different protocols of explosive power for lower limbs (boys)

Figure 5.a. predicts a strong positive correlation between the SJ and the CMJ, these two protocols having a directly proportional relationship in the evaluation of explosive power. The same trend can also be seen in *Figure 5.b.*, that the results obtained by the boys in the Squat Jump will follow the same trajectory as those recorded in the Abalakov's Jump, with the evolution of the explosive power performance being similar.

Table 8. Pearson correlation (r) between explosive power (Countermovement Jump) and isometric strength (boys)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Countermovement Jump	***Abalakov's Jump***		0.927**	0.000
Countermovement Jump	***Isometric strength LL – Add. Pres.***		-0.050	0.800
Countermovement Jump	***Isometric strength UL – Pres.***	28	0.109	0.580
Countermovement Jump	***Isometric strength UL – Trac.***		0.208	0.287

*** Correlation is significant at the 0.01 level (2-tailed).*

The Countermovement Jump values were statistically significantly correlated with the explosive power measured by Abalakov's Jump (r = 0.927, p<0.001). In contrast, no correlation between CMJ and isometric strength (p>0.05) was found among the boys sample (*Table 8*).

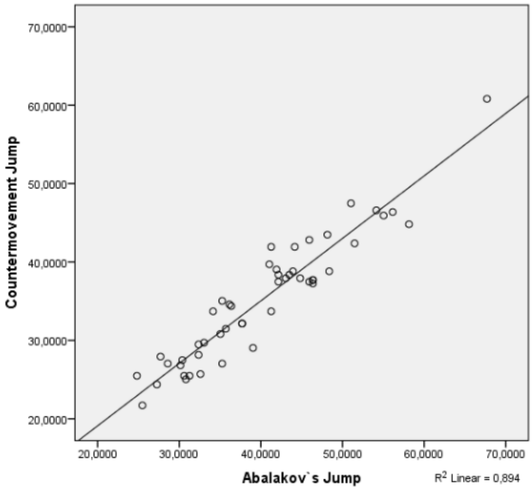

Fig. 6. Pearson correlation graph between Countermovement Jump and Abalakov's Jump (explosive power - boys)

Figure 6 shows the strong association between CMJ and Abalakov lower limb explosive power tests. This positive correlation indicates that performance on the two protocols will have similar trends.

The results in *Table 9* demonstrate the same situation found in the girls' sample, the explosive power as measured by Abalakov's Jump did not correlate with the isometric strength as determined by the 3 protocols (p>0.50).

Table 9. Pearson correlation (r) between explosive power (Abalakov's Jump) and isometric strength (boys)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Abalakov's Jump	***Isometric strength LL – Add. Pres.***		-0.155	0.431
Abalakov's Jump	***Isometric strength UL – Pres.***	28	-0.054	0.786
Abalakov's Jump	***Isometric strength UL – Trac.***		0.070	0.722

As in the case of girls, the results obtained by adolescent boys when testing isometric upper limb isometric strength by the two protocols, pressure and traction, show a statistically significant correlation (r = 0.396, p<0.050) (*Table 10*).

Table 10. Pearson correlation (r) between different protocols of isometric strength for upper and lower limbs (boys)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Isometric strength LL – Add. Pres.	***Isometric strength UL – Pres.***	28	0.266	0.172
Isometric strength LL – Add. Pres.	***Isometric strength UL – Trac.***		0.215	0.272
Isometric strength UL – Pres.	***Isometric strength UL – Trac.***		0.396*	0.037

** Correlation is significant at the 0.05 level (2-tailed).*

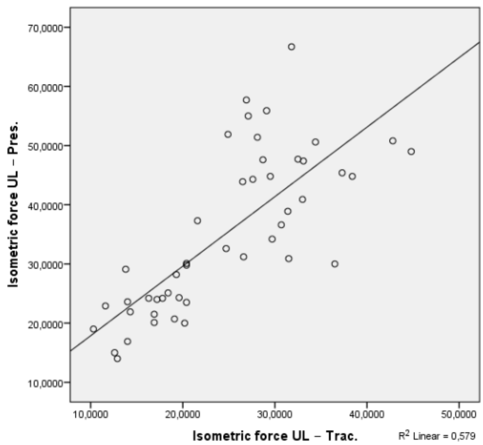

Fig. 7. Pearson correlation graph between isometric strength protocols for upper limbs (boys)

Figure 7 indicates an acceptably-moderate positive regression trajectory for the pressure and tensile protocols of the upper limb isometric strength test. Thus, if high values are recorded for the pressure test, the same situation will follow for the upper limb isometric strength test by traction.

For the whole sample, explosive power testing by Squat Jump correlated statistically significantly with the CMJ (r = 0.964, p<0.001) and Abalakov (r = 0.931, p<0. 001), which determine the same variable, as well as with the isometric strength tests of the lower limb (r = 0.567, p<0.001) and upper limb, both pressure (r = 0.594, p<0.001) and pull (r = 0.642, p<0.001) (*Table 11*).

Table 11. Pearson correlation (r) between explosive power (Squat Jump) and isometric strength (overall)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Squat Jump	***Countermovement Jump***	49	0.964**	
Squat Jump	***Abalakov's Jump***	49	0.931**	
Squat Jump	***Isometric strength LL – Add. Pres.***	47	0.567**	0.000
Squat Jump	***Isometric strength UL – Pres.***	47	0.594**	
Squat Jump	***Isometric strength UL – Trac.***	47	0.642**	

*** Correlation is significant at the 0.01 level (2-tailed).*

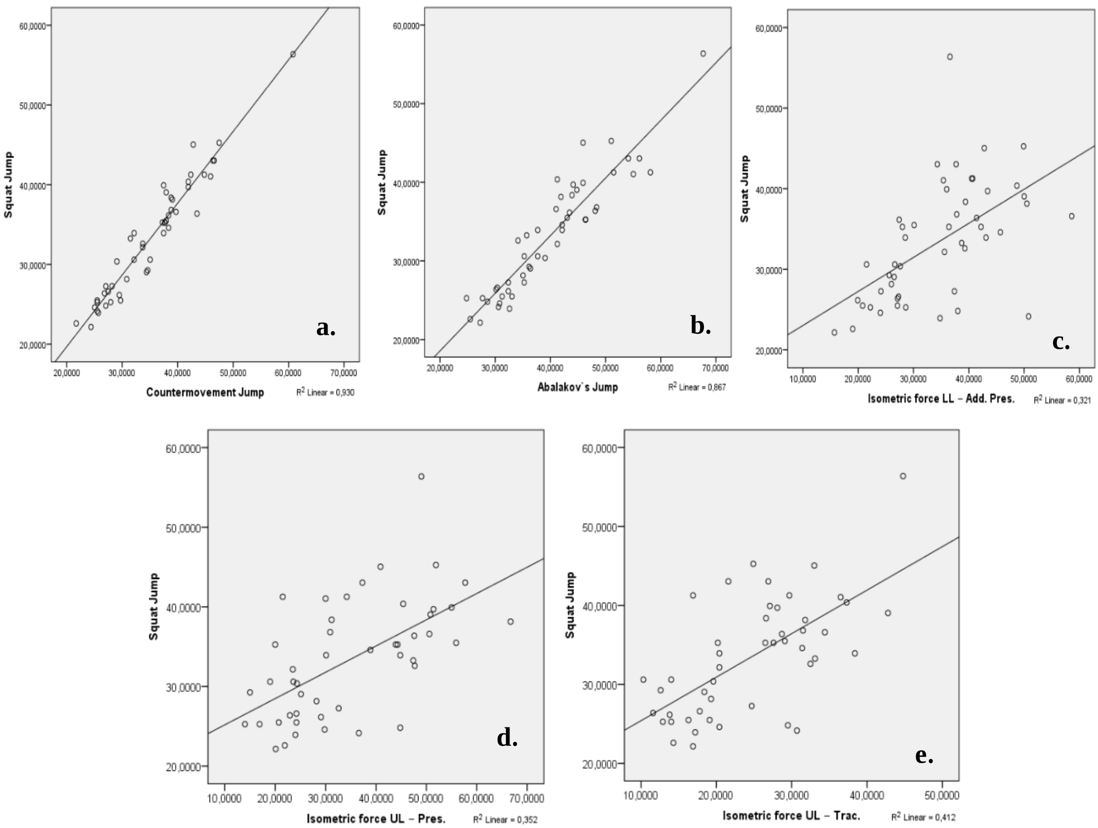

Fig. 8. Pearson correlation graph between explosive power (Squat Jump) and isometric strength (overall)

Figure 8 shows 2 strong positive correlations between the explosive power rendered by Squat Jump, Countermovement Jump (*Figure 8.a.*) and Abalakov's Jump (*Figure 8.b.*), with a directly proportional relationship between these three protocols. Thus, the high performances obtained in the SJ test are associated with similar values in the CMJ and Abalakov test. There are also three moderately strong positive relationships between explosive power (SJ test) and isometric strength of the lower limbs determined by pressure (*Figure 8.c.*) and isometric strength of the upper limbs determined by the pressure (*Figure 8.d.*) and traction (*Figure 8.e.*) protocols. Subjects who perform significantly on the SJ test will have the same trajectory among the values obtained on the three isometric tests.

According to the results in *Table 12*, CMJ was statistically significantly correlated with Abalakov ($r = 0.945$, $p<0.001$), as well as with isometric strength of the lower limb ($r = 0.514$, $p<0.001$) and upper limb (pressure: $r = 0.540$, $p<0.001$, traction: $r = 0.598$, $p<0.001$).

Table 12. Pearson correlation (r) between explosive power (Countermovement Jump) and isometric strength (overall)

Parameter 1	**Parameter 2**	**N**	**Pearson correlation coefficient (r)**	**p**
Countermovement Jump	***Abalakov's Jump***	49	0.945**	0.000
Countermovement Jump	***Isometric strength LL – Add. Pres.***	47	0.514**	
Countermovement Jump	***Isometric strength UL – Pres.***	47	0.540**	
Countermovement Jump	***Isometric strength UL – Trac.***	47	0.598**	

*** Correlation is significant at the 0.01 level (2-tailed).*

Just as in the case of the SJ protocol, according to *Figure 9*, a strong positive correlation is observed between the explosive power and Abalakov's Jump (*Figure 9.a.*), the ratio between the 2 being directly proportional. Between the explosive and isometric strength of the lower (pressure - *Figure 9.b.*) and upper limbs (pressure - *Figure 9.c.* and traction - *Figure 9.d.*), as rendered by the 3 protocols, there are three positive links with moderate intensity, thus those who perform significantly in the CMJ test will have the same trajectory among the values obtained in the isometric strength tests.

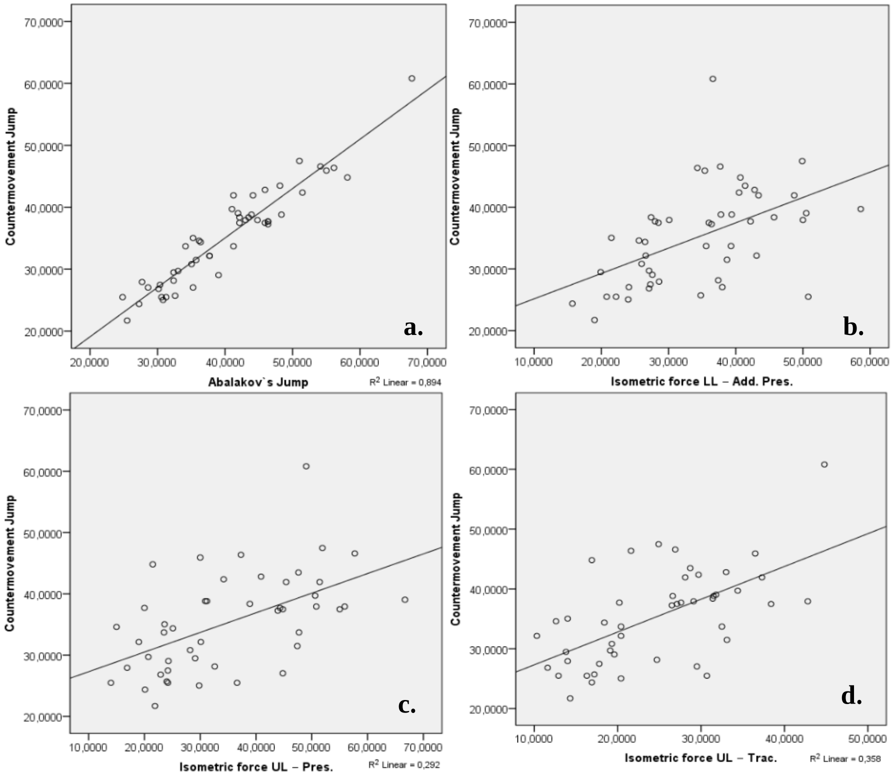

Fig. 9. Pearson correlation graph between explosive power (Countermovement Jump) and isometric strength (overall)

Table 13 indicates statistically significant correlations between Abalakov's Jump and isometric strength of the lower limb, determined by pressure (r = 0.457, p<0.001), and upper limb, determined by pull (r = 0.457, p<0.001), for both protocols: pressure - r = 0.461, p<0.001, pull - r = 0.541, p<0.001).

Table 13. Pearson correlation (r) between explosive power (Abalakov's Jump) and isometric strength (overall)

Parameter 1	Parameter 2	N	Pearson correlation coefficient (r)	p
Abalakov's Jump	***Isometric strength LL – Add. Pres.***		0.457**	
Abalakov's Jump	***Isometric strength UL – Pres.***	47	0.461**	0.000
Abalakov's Jump	***Isometric strength UL – Trac.***		0.541**	

*** Correlation is significant at the 0.01 level (2-tailed).*

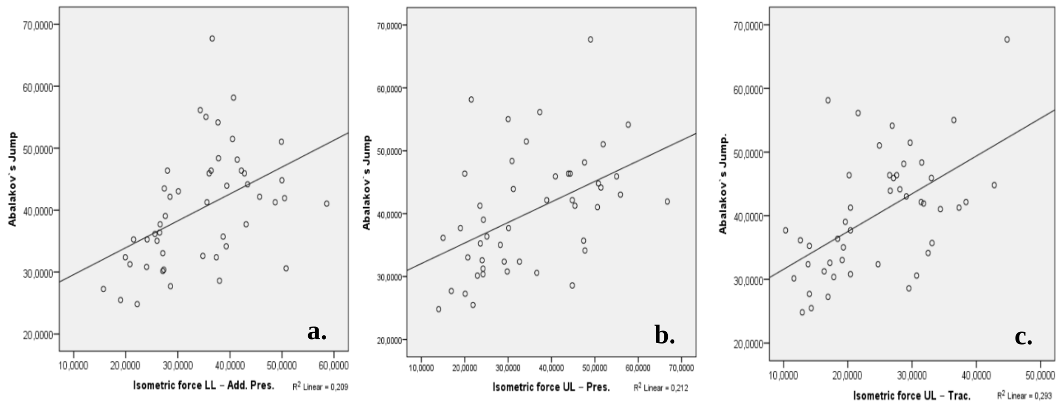

Fig. 10. Pearson correlation graph between explosive power (Abalakov's Jump) and isometric strength (overall)

The explosive power (Abalakov's Jump) shows moderate relationships with the isometric strength, as determined by pressure, of the lower (*Figure 10.a.*) and upper (*Figure 10.b.*) limbs. In contrast, there is a strong positive correlation between the arm-elbow jump protocol and the isometric strength of the upper extremity as determined by pull (*Figure 10.c.*).

The explosive power testing protocols formed statistically significant relationships with each other. The lower train strength correlated with the upper train strength, as rendered by pushing the handles (r = 0.657, $p<0.001$) and pulling the handles (r = 0.690, $p<0.001$). Connections were also observed between the two methods of testing isometric hand strength (r = 0.761, $p<0.001$) (*Table 14*).

Table 14. Pearson correlation (r) between different protocols of isometric strength for upper and lower limbs (overall)

Parameter 1	**Parameter 2**	**N**	**Pearson correlation coefficient (r)**	**p**
Isometric strength LL – Add. Pres.	***Isometric strength UL – Pres.***		0.675**	
Isometric strength LL – Add. Pres.	***Isometric strength UL – Trac.***	47	0.690**	0.000
Isometric strength UL – Pres.	***Isometric strength UL – Trac.***		0.761**	

*** Correlation is significant at the 0.01 level (2-tailed).*

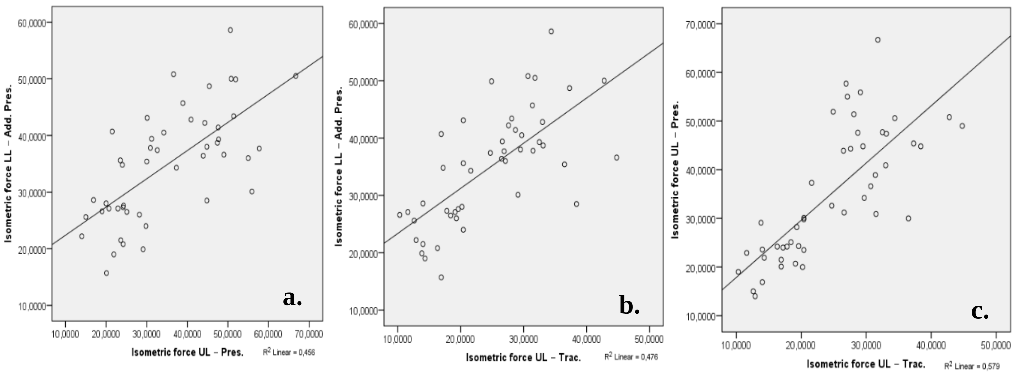

Fig. 11. Pearson correlation graph between isometric strength protocols for upper and lower limbs (overall)

According to the graphs in *Figure 11*, moderate positive correlations were found between the isometric lower-train isometric strength with the isometric arm strength tests by pressure (*Figure 11.a.*) and tension (*Figure 11.b.*). A strong positive correlation was observed between the two protocols for measuring isometric upper-train isometric strength (*Figure 11.c.*).

DISCUSSIONS

Our research has determined links between explosive (SJ, CMJ, Abalakov) and isometric strength of the upper (pressure and traction measurements) and lower limbs. Among girls, isometric strength correlations were found between lower and upper extremity isometric strength as well as between the two methods of measuring hand isometric strength. In adolescent boys, however, only a statistically significant correlation was observed between the two upper limb isometric strength testing procedures.

This association supports data in the literature showing a strong link between the ability to generate maximal or near maximal isometric strength with the ability to produce explosive power in dynamic movements, particularly when isometric tests are biomechanically positioned similarly to dynamic movement (Pasfield et al., 2024, Grzyb et al., 2025; Akoğlu et al., 2025; Shiba, 2023). Similarly, Fahey et al. (2025) found in adolescent female soccer players moderate-to-strong correlations between relative isometric strength (IMTP) and CMJ/Rebound-Jump performance. França et al. (2023) revealed that upper limb strength (handgrip) is one of the fundamental predictors of vertical jumps.

Similar to the age range of our study, Rago et al. (2024) found moderately-strong correlations (r = 0.61-0.78) between isometric strength measured by Isometric Mid-Thigh Pull (IMTP) and Countermovement Jump Height (CMJ) among young athletes (13-17 years). Naim et al. (2024) tested a group of professional football players and found correlations between handgrip strength and isometric lower limb isometric strength (r = 0.52) and CMJ jump. The same conclusion was determined by Ferrero-Hernández et al. (2023), who analyzed adolescents in Europe. Relative to gender, Patti et al. (2022) showed an association between upper limb strength (handgrip) and strength at CMJ, with values of r = 0.60 among boys and r = 0.48 among girls.

Some authors have concluded that strength, speed and agility correlate in adolescents. These studies observing adolescent development contribute to our understanding of how the body behaves physically during a period of biological change (Trofin et al., 2023).

Possible mechanisms that explain these correlations include neuromuscular factors (motor activation and coordination), muscle-tendon properties (stiffness/elasticity) and strength transfer between segments (e.g. role of the arms in Abalakov jump performance). Data from the literature concluded that isometric variables (peak strength, rate of strength development), obtained from standardized tests (IMTP or specific isometric tests), can contribute to a better understanding of the variation in jumping performance, especially when biological maturation and body composition are taken into account (Rago et al., 2024, Dobbs et al., 2020). Hughes et al. (2022) concluded that the strength-time analysis of SJ and CMJ protocols shows that isometric parameters (RFD and peak strength) determine more than 50% of the jump variability.

Another variable on which the correlations of the present study may depend is the process of biological maturation. Some studies indicate that, in adolescence, the pattern of muscle mass development and its distribution may influence both isometric strength and jumping performance (explosive power), and these processes are shaped by variations in biological maturation. França et al. (2023) recommending gender-relative data interpretation. The studies by Curović et al. (2024) and Correia et al. (2024) support the hypothesis that there is a relationship between upper-train strength and vertical jump performance.

CONCLUSION

The results of the study showed significant correlations between lower extremity explosive power, as measured by Squat, Countermovement and Abalakov jumps, and isometric lower and upper extremity strength. These links confirm the literature evidence that explosive performance is closely related to the neuromuscular ability to rapidly develop maximal strength, regardless of the body segment involved (Grzyb et al., 2025; Rago et al., 2024; Akoğlu et al., 2025).

The correlations identified in the fetor group, between isometric adductor and upper extremity tensile isometric strength, may suggest the existence of a global strength profile, which may be influenced by factors such as biological maturity and intersegmental coordination. Some specialists support the hypothesis that the balanced development of upper and lower muscle chains favors dynamic performance and reduces the risk of functional imbalances (Curović et al., 2024; Correia et al., 2024; Correia et al., 2024; Quintana-Cepedal et al., 2024).

The present study concluded that the strength of the lower limb muscles, particularly those involved in vertical jump execution, significantly influences jump performance. This association was most evident across the total sample, suggesting that isometric lower-limb strength contributes meaningfully to explosive performance capacity. However, since these relationships were predominantly observed in the combined group rather than consistently across genders, further studies with larger and more balanced samples are required to confirm and clarify gender-specific patterns.

AUTHOR CONTRIBUTIONS

Coteață Maria-Andreea and Ungurean Bogdan-Constantin contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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FEMALE STUDENTS' PERCEPTIONS OF MALE PARTICIPATION IN RHYTHMIC GYMNASTICS

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ABSTRACT. *Introduction*: Rhythmic gymnastics has been recognized as an Olympic sport for women since 1984, distinguished by its emphasis on grace, flexibility, and the artistic integration of music and apparatus. Historically perceived as a female-exclusive discipline, this perception has been shaped by prevailing societal constructs of masculinity, which prioritize strength, competitiveness, and emotional restraint. However, an increasing number of countries are now promoting male participation in rhythmic gymnastics, thereby challenging traditional gender norms. Within a socially rigid framework, sport continues to play a pivotal role in constructing and reinforcing gender identities, often presenting masculinity and femininity as natural and complementary categories. *Aim:* The aim of this study is to identify the level of acceptation of male's rhythmic gymnastics by the younger generation through female students of the Faculty of Physical Education and Sport, who are studying this sport in their first year. *Methods*: The study was conducted on 101 female students of Physical Education and Sport Faculty from Timisoara. The questionnaire survey method was used in this research. This was developed specifically for this study and distributed to female students for complete to all four specializations. *Results*: The questionnaire reveals growing acceptance of male rhythmic gymnastics. When asked "Do you practice any sport?", responses were nearly split: 49.5% said "Yes" and 50.5% "No." A majority (63.4%) believe the sport isn't exclusive to women and support male inclusion in training, education, and competition. If they were PE teachers, 76.2% of female students would teach rhythmic gymnastics to boys. Moreover, 79.2% think the Romanian Rhythmic Gymnastics Federation should officially introduce the discipline. Regarding boys performing in tights, 66.3% were unbothered, 18.8% were enthusiastic, 12.9% indifferent, while only 2% expressed discomfort. *Conclusion*: The results indicate a clear shift toward greater inclusivity and gender diversity in rhythmic gymnastics.

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The openness to formalizing male participation, integrating the discipline into boys' education, and embracing cultural change reflects evolving attitudes among the younger generation. The predominance of positive responses and minimal resistance suggest meaningful progress in challenging traditional gender norms. However, to strengthen the relevance and impact of these findings, further research is needed to explore broader perspectives and long-term implications.

Keywords: rhythmic gymnastics for male, female students, gender differences, inclusion through sport

INTRODUCTION

Sports have traditionally been male dominated, with women gaining participation and representation gradually. Despite progress, women still face fewer opportunities, limited governance roles, and a gender pay gap, especially in sports like cricket and football. Female coaches remain underrepresented, and media coverage heavily favors male athletes (Katsarova, 2019). However, in two sports disciplines, synchronized swimming and rhythmic gymnastics, boys are excluded from official competitions, because the traditional masculinity has been shaped by ideals such as strength, aggression, competitiveness, and heterosexuality (Piedra, 2020). Despite significant progress in promoting gender inclusiveness in sports, boys remain excluded from official competitions in two specific disciplines, synchronized swimming and rhythmic gymnastics. This limitation highlights ongoing barriers to achieving full gender equity in all areas of sports.

According to International Federation of Gymnastics, Rhythmic Gymnastics, sister sport of Artistic Gymnastics, has its roots in antiquity and even outdate the Gymnastics of the Ancient Greeks. The institute Dalcroze founded in Geneva continues to teach rhythmic gymnasts using the eurhythmics methods he first pioneered. First dubbed "Modern Gymnastics", the sport of Rhythmic Gymnastics held its first World Championships in Budapest in 1963, the same year Rhythmic became a FIG discipline. Rhythmic gymnastics is a Olympic female sport since 1984.

Even though sports are often perceived as a predominantly male domain, there are two disciplines—rhythmic gymnastics and synchronized swimming—where male participation remains underrepresented, challenging traditional gender norms and inviting broader inclusivity. Recently the tendency of changing on gender inequalities in sport, introduced athletes of both genders in sports characterized by only one gender (Di Cagno et al., 2009).

According to Colley & Comber, 2003, there is still evidence of continuing presence in gender differences, and this situation can only be attributed to a more enduring influence by societal gender roles and beliefs associated with them.

Because certain sports were categorized as sex-related due to social pressure, the entry of men into female sports was difficult. The selection of sports activities is frequently influenced by the performance's masculinity and femininity ratings. The persistence of gender preferences is influenced by gender stereotypes, especially in the case of younger individuals (Zinkhan et al., 2004).

In Japan, this sport is quite popular, with over 1,000 practitioners, and competitions include elements inspired by martial arts, such as wushu. Spain is the first European country to recognize men's rhythmic gymnastics, and gymnasts like Ruben Orihuela have been pioneers in this field. Although there are national championships and demonstrations, men's rhythmic gymnastics has not yet been included in the Olympic Games. However, there are discussions about adapting a specific scoring code for male movements so that they can be better represented in international competitions (Kamberidou et al., 2009).

Over the past two decades, men have been advocating for equal opportunities in competitive rhythmic gymnastics, urging International Gymnastics Federation (FIG) to act toward officially recognizing men's rhythmic gymnastics as a sport. Male rhythmic gymnastics teams are active in countries such as Japan, Australia, Canada, the United States, Russia, Korea, Malaysia, Mexico, Greece, Spain, and Italy. An increasing number of male gymnasts are participating in various formats—solo, individual, team, and even mixed pair—although these events remain unofficial, as FIG currently acknowledges only women's rhythmic gymnastics (Kamberidou et al., 2009).

Progress towards gender equality in sports, promoted by UNESCO, the IOC, and other international organizations, remains slow and uneven. Despite initiatives such as the Brighton Declaration and Kazan Action Plan, further steps are needed to combat stereotypes, misogyny, and structural barriers affecting girls and women globally (de Soysa et al. 2019).

According to the International Olympic Committee (IOC), the first women's Olympic Games were held in 1900. Over a century later, the London 2012 Olympics marked a significant milestone, being the first edition where every nation had at least one female athlete. In 2024, the Paris Olympics made history by achieving full gender parity, with an equal number of male and female athletes participating.

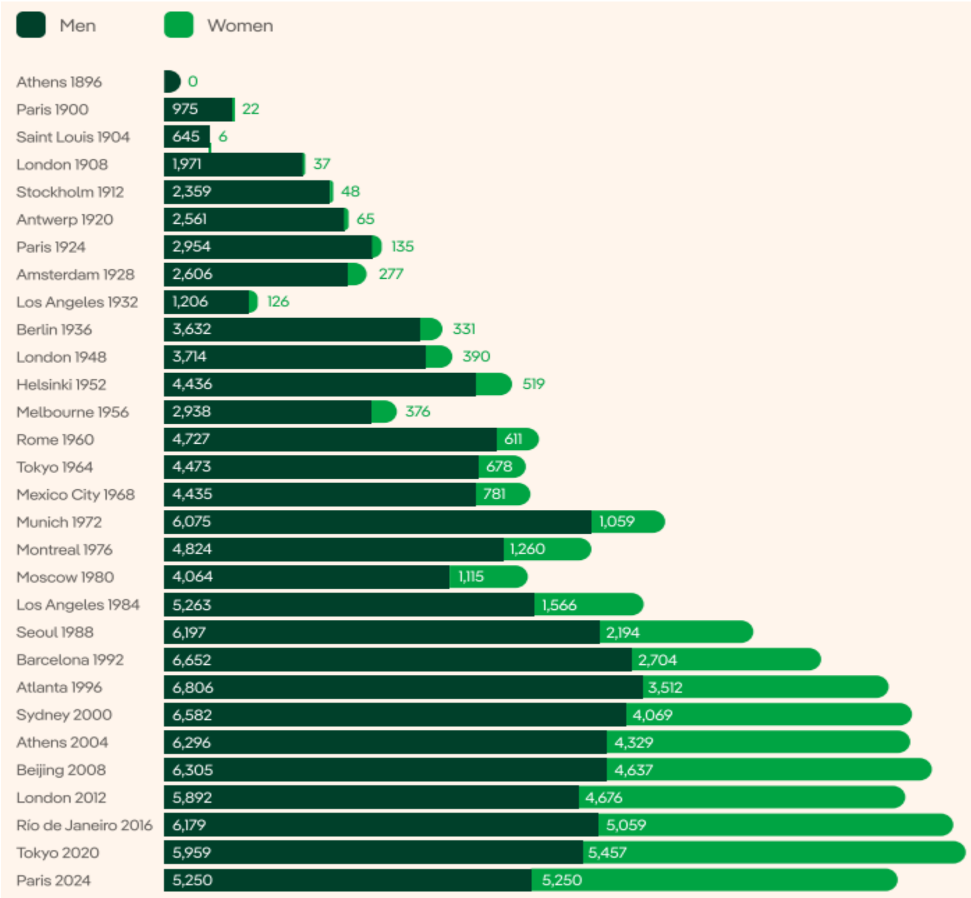

Fig. 1. International Olympic Committee (IOC)

One article published by TIME (Stern, 2024), at the 2024 Paris Olympics, although the International Olympic Committee allowed men to participate in artistic swimming for the first time, no male athletes will compete. This absence is explained by the difficulty of integrating men into a sport historically perceived as feminine, despite its mixed origins. The evolution and media representation of artistic swimming have emphasized its aesthetic and feminine aspects, leading to the exclusion of men for decades. Although the U.S. reinstated male participation in 1979 and mixed duet became an international competition in 2015, the full inclusion of male teams remains challenging due to differences in physique and swimming styles. According to journal TIME (Stern, 2024), Bill May, an advocate for male participation in this sport, did not qualify for the U.S. Olympic team, highlighting the need for experience and diversity in competition.

Also, the Euronews article discusses the exclusion of male athletes from artistic swimming at the Paris 2024 Olympics, despite the International Olympic Committee allowing their participation. It highlights concerns about gender equality in the Games, noting that no men were selected among the 96 athletes competing in the event. The article explores the historical perception of artistic swimming as a female-dominated sport and the challenges male athletes face in gaining recognition. It also mentions disappointment from World Aquatics, which had hoped to see male competitors in Paris. Additionally, the piece touches on the broader efforts to achieve gender balance in Olympic sports (Euronews, 2024).

Regarding the rhythmic gymnastics, Rubén Orihuela from Spain, started rhythmic gymnastics at the age of 10, in a sport traditionally considered feminine. In 2005, the Spanish Gymnastics Federation (RFEG) allowed men to participate in the Open category of the National Individual Championship, but this decision was overturned in 2009 by the International Gymnastics Federation (FIG), which stated that rhythmic gymnastics is exclusively for women. Following criticism, RFEG established a separate Men's National Championship, with the first edition taking place in 2009 in Gijón, where Orihuela won in the senior category. He won numerous national titles between 2007 and 2016, as well as a bronze medal in 2015 and a silver in 2017 (Orihuela, 2025).

- Has anyone critically examined the fact that male athletes do not have representation in all disciplines at the Olympic Games?
- Is gender equality also addressed for boys who wish to participate in female sports?
- Currently, there is no official global statistic on the number of boys practicing rhythmic gymnastics. However, it is estimated that several thousand athletes are involved in this field at the local level, either within sports clubs or by participating in unofficial competitions boys practicing rhythmic gymnastics, why does the International Gymnastics Federation not allow them to officially compete in recognized tournaments?
- How do girls perceive male gender equality in this context, and what are their opinions on the matter?

In the rigid social framework, physical activity and sport have served—and continue to serve—as influential arenas for shaping and reinforcing gender identities, portraying masculinity and femininity as natural and complementary roles (Piedra, 2017).

MATERIAL AND METHOD

For the present study we used a questionnaire with 15 questions referring to the practice of rhythmic gymnastics by males. This questionnaire was applied on 101 female students of the Faculty of Physical Education and Sport, students who had participated during their studies in the rhythmic gymnastics course, in conclusion they had knowledge related to this discipline. Students included in the study came from all specializations of the faculty in all 3 years of bachelor studies. We chose to interview only female students to understand the perception of the young female generation on gender equality or social inclusion through sport.

RESULTS

The results of the survey reflect the perceptions and opinions of the young female generation on males' rhythmic gymnastics and gender issues. This data is key to understanding how social and cultural changes influence perceptions of gender inclusion and equality in sport. By examining these graphs, we can observe emerging trends and the level of acceptance of males in rhythmic gymnastics, both nationally and internationally.

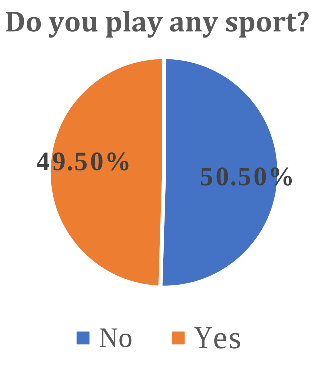

Fig. 2. Graphical representation of female students who practice or do not practice any sport

"Do you practice any sport?" and represents the responses of 101 individuals. It is divided into two sections:

"Yes" (DA), shown in orange, accounts for 49,50% of the responses.

"No" (NU), shown in blue, makes up 50,50% of the responses.

This indicates that slightly more than half of the surveyed individuals do not practice any sport, while just under half do. It offers an interesting insight into the balance of physical activity within this group.

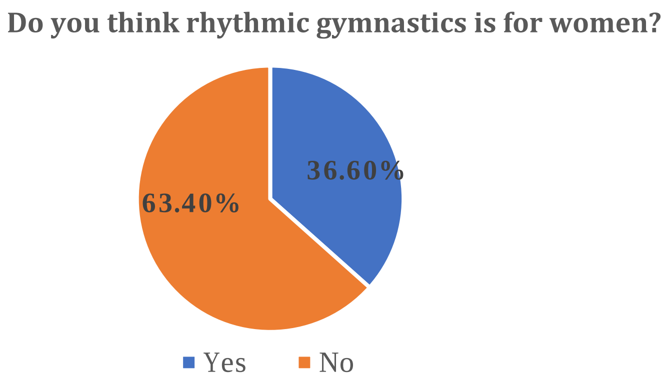

Fig. 3. Graphical representation of female students' opinions on practicing rhythmic gymnastics

"Do you think rhythmic gymnastics is dedicated to women?". As the data show, only 36.60% of respondents believe that this sport is exclusively for women ("Yes"), while a significant majority, 63.40%, believe the opposite ("No"). This may suggest a change in perspectives or a greater openness to the idea of inclusivity in this sport.

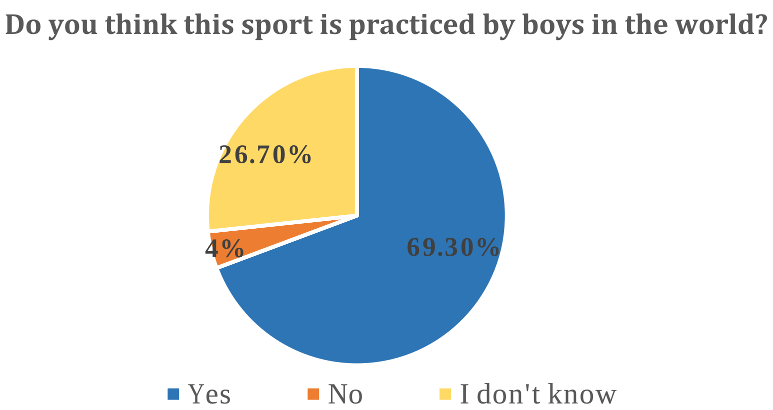

Fig. 4. Graphical representation of students' perceptions regarding male participation in rhythmic gymnastics worldwide

The graph is a pie chart that answers the question: “Do you think this sport is practiced by males in the world?” and has 101 answers. The results are as follows:

- “Yes” (blue): 69.30% of respondents believe that this sport is practiced by males globally.

- “No” (orange): 4% think it is not practiced.

- “I don’t know” (yellow): 26,70 % a small percentage of respondents are not sure.

This shows a majority opinion that the sport is practiced by males worldwide. It may suggest a growing awareness or openness towards males’ involvement in the sport.

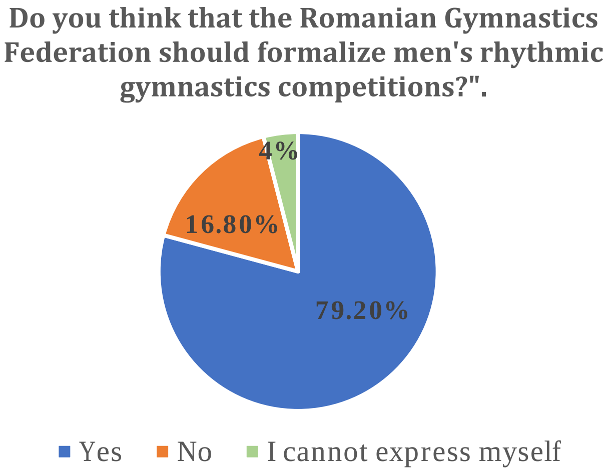

Fig. 5. Graphical representation of students’ opinions on whether the Romanian Gymnastics Federation should formalize men’s rhythmic gymnastics competitions

“Do you think that the Romanian Gymnastics Federation should formalize men’s rhythmic gymnastics competitions?”. The results of the poll are as follows:

- “Yes” (represented in blue): 79.20% of participants support the formalization of competitions for men’s rhythmic gymnastics.

- “No” (represented in orange): 16.80% of respondents are against this initiative.

- “I cannot express myself” (represented in green): 4% of the respondents do not have a clear opinion.

This graph shows a clear majority in favor of officialization, suggesting a desire for change and a greater openness towards the inclusion of men’s rhythmic gymnastics in official competitions. It is a positive signal for diversity and evolution in sport.

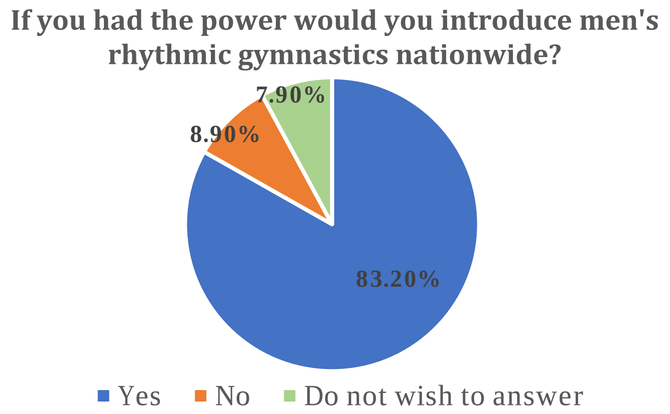

Fig. 6. Graphical representation of students' support for introducing men's rhythmic gymnastics nationwide

"If you had the power, would you introduce men's rhythmic gymnastics nationwide?" The survey includes 101 responses, and the results are divided as follows:

- "Yes" (represented in blue): 83.20% of respondents would introduce men's rhythmic gymnastics nationally.
- "No" (represented in orange): 8.90% would refuse this initiative.
- "Do not wish to answer" (represented in green): 7.90% did not express an opinion.

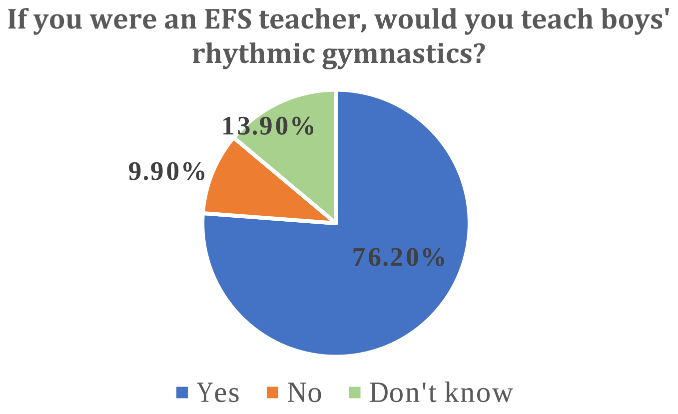

Fig. 7. Graphical representation of students' willingness to teach boys rhythmic gymnastics as future EFS teachers

These data indicate strong support for the proposed initiative, with a clear majority in favor of the introduction of men's rhythmic gymnastics. The results suggest a desire for diversification and inclusion in national sport.

"If you were an EFS teacher, would you teach boys' rhythmic gymnastics?". The 101 answers are distributed as follows:

- "Yes" (represented in blue): 76.20% of the respondents consider that they would teach rhythmic gymnastics to boys.
- "NO" (represented in orange): 9.90% of the respondents would not.
- "Don't know" (represented in green): 13.90% of respondents are not sure.

These percentages reflect a majority support for teaching boys rhythmic gymnastics, which may suggest a positive change in perceptions of inclusion in PE.

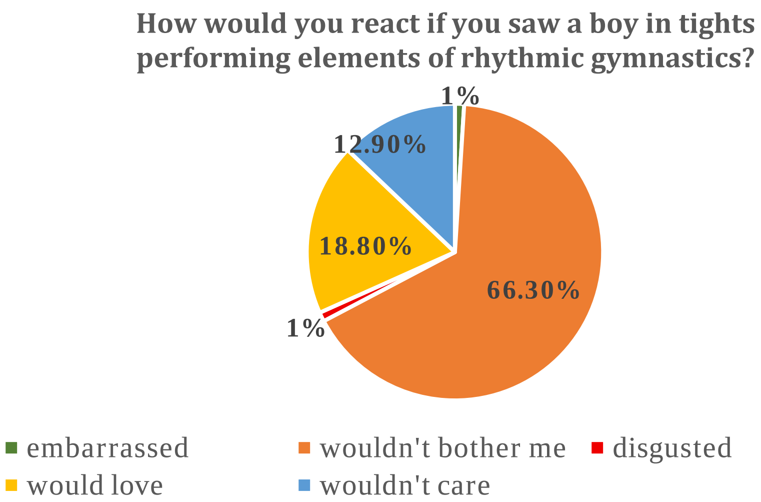

Fig. 8. Graphical representation of students' reactions to boys performing rhythmic gymnastics in tights

"How would you react if you saw a boy in tights performing elements of rhythmic gymnastics?". With 101 responses analyzed, the results are as follows:

- 66.30% (orange): most respondents said they "wouldn't bother me" seeing this.
- 18.80% (yellow): Respondents said, "would love".
- 12.90% (blue): Respondents said, "wouldn't care".
- 1% (green): Few respondents answered "embarrassed".
- 1% (red): A similar percentage said they would be 'disgusted'.

This suggests a largely positive or neutral attitude towards men's rhythmic gymnastics, with a small minority having negative reactions.

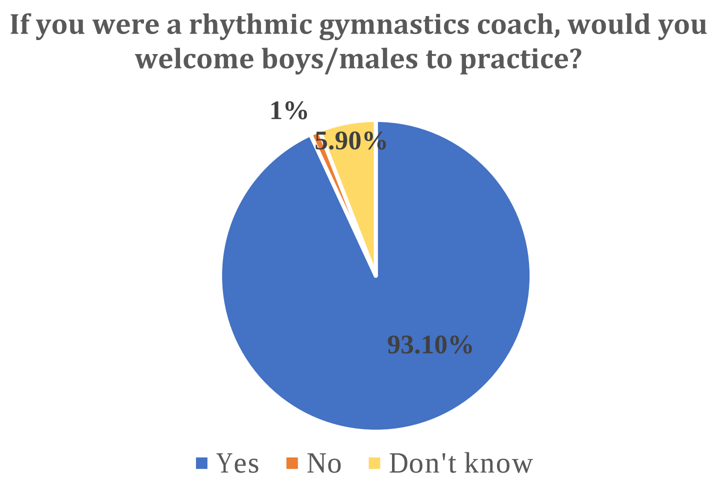

Fig. 9. Graphical representation of students' openness to welcoming boys into rhythmic gymnastics as future coaches

"If you were a rhythmic gymnastics coach, would you welcome boys/males to practice?" and includes 101 responses. The results are split as follows:

- "Yes" (represented in blue): 93.10% of the respondents would accept boys in rhythmic gymnastics training.
- "No" (represented in orange): A very small percentage would not (1%).
- "Don't know" (represented with yellow): Another small percentage is not sure, 5.90%.

These data suggest overwhelming support for the inclusion of boys in rhythmic gymnastics training, indicating a broad openness to diversity in the sport.

DISCUSSION

Dowling (2006) examines how Norwegian physical education teacher educators define their professional roles and approach gender equality. Dowling show that their focus is mostly technical—centered on teaching sports skills—while issues of gender are often ignored or seen as biological facts. Their professional development is individual and rooted in personal interests, with little collaboration or critical reflection. Their study suggests that deeper awareness and dialogue about gender could lead to more inclusive practices in PETE.

Organista, Mazur, Larsson and Lenartowicz (2024) state that **male PE teachers unintentionally reinforce heteronormative gender roles** through their communication with students—especially girls. Although the teachers "don't have bad intentions," their jokes and comments about appearance, dating, and femininity help **normalize traditional gender expectations** and heterosexuality as the default. The authors emphasize that teachers often **lack awareness of how their words shape gender dynamics,** and students—having internalized these norms—rarely question them. They argue that **gender-sensitive education for both teachers and students is essential** to challenge these ingrained patterns.

Biemmi (2015), argues that, contrary to popular belief, the Italian school system continues to mirror and reinforce societal gender inequalities. Biemmi highlights three main areas of concern: the gendered nature of educational choices, which limits girls' access to lucrative careers; persistent sexist stereotypes in textbooks, where women are portrayed in domestic roles while men dominate public life; and the lack of teacher training in gender sensitivity, which contributes to the unintentional perpetuation of these biases. Although Italian research on gender and education has been substantial, it has only recently begun to influence policy, with promising legislative and academic efforts emerging since 2013.

Despite the literature reviewed above, there is limited evidence acknowledging that gender-related issues may also affect boys. Female physical education teachers may unintentionally enact gender-based discrimination during PE lessons. In the context of our article, which focuses on boys' participation in rhythmic gymnastics, gender-related challenges frequently arise in the way teachers—both male and female—approach the subject. In conclusion, this topic requires more thorough investigation to understand the trajectory it is taking within a rapidly evolving society.

CONCLUSION

A significant percentage of respondents do not participate in any sports, which could point to a broader disinterest or barriers to engagement in physical activities. Nevertheless, the majority perceive rhythmic gymnastics as a discipline that is not exclusively tailored for women, showcasing an evolving mindset toward gender inclusivity in sports. This shift is further reflected in the growing support for boys/males practicing rhythmic gymnastics worldwide, signaling an emergent trend that embraces diversity and challenges traditional stereotypes.

Young women support a future initiative to formalize men's rhythmic gymnastics competitions in Romania, thus highlighting a collective desire for institutional recognition and transformative change in the sports arena. This enthusiasm is reflected by a substantial proportion of respondents who are open to accepting the introduction of men's rhythmic gymnastics at the national level, revealing a strong desire for diversification and wider acceptance in the sporting community.

Moreover, the majority's willingness to teach rhythmic gymnastics to boys is emblematic of a cultural shift in educational practices, favoring inclusivity and representation in physical education. The predominantly positive or neutral reactions to boys wearing leotards and performing rhythmic gymnastics elements emphasize societal progress in breaking down barriers of conventional gender roles. The minimal negativity further underscores the changing attitudes and openness among communities.

In conclusion, the overwhelming support for the integration of boys/males in rhythmic gymnastics training serves as a testament to the progressive acceptance and celebration of diversity in sport, paving the way for a more inclusive and equitable future in sporting endeavors. Specialized rules could be developed for males rhythmic gymnasts to enhance their performance by tailoring aspects such as equipment, music, and movement, while ensuring adherence to the fundamental principles of the discipline.

To be able to conclude that rhythmic gymnastics is considered by Romanian people a sport for both women and men, further in-depth studies are needed.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the conception, design, data collection, analysis, and writing of this manuscript. All authors approved the final version for publication.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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EFFECTS OF A MULTICOMPONENT BALANCE AND STRENGTH TRAINING PROGRAM ON POSTURAL STABILITY IN OLDER ADULTS: A REPEATED-MEASURES ANALYSIS

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ABSTRACT. Aging is characterized by a progressive decline in balance and mobility, leading to an increased risk of falls among older adults. This pilot study investigated the effects of a multicomponent balance and strength training program on postural control in community-dwelling older adults. Four participants (two men, two women; age 72–94 years, M = 79.0, SD = 9.9) completed a 6-week intervention consisting of thrice-weekly sessions (20–25 minutes, light-to-moderate intensity) including warm-up, progressive balance/strength exercises and cool-down. Postural stability was assessed using a BTS P-WALK baropodometric platform under six conditions: quiet standing and half-squat position with eyes open then closed, each on hard and soft surfaces. Thirty-six center-of-pressure variables (area, path length, velocity) were analyzed at three time points (baseline, intermediate, final). Given the small sample size (N = 4) and some non-normally distributed variables, Friedman's test was used. No statistically significant differences were found across time (all $p \geq .105$). However, descriptive trends indicated modest improvements in sway area, path length, and velocity under eyes-open and half-squat conditions, suggesting enhanced postural stability.

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Although underpowered, this study highlights the feasibility of implementing multicomponent balance training in older adults and suggests potential benefits for fall prevention. The absence of decline in postural stability itself may be clinically relevant. Future larger-scale trials with longer follow-up are needed to confirm these findings and to explore whether improvements in force-platform metrics translate into meaningful reductions in fall risk.

Keywords: Older adults; Balance training; Strength training; Postural control; Center of pressure (CoP); Half-squat position; Multicomponent exercise program; Fall prevention.

INTRODUCTION

As life expectancy has increased, so did the prevalence of falls among the elderly. A fall is the consequence (a symptom) of a disease. It is the leading cause of morbidity and mortality among older adults, so its prevention must be a public health priority (Rubenstein, 2006). Aging comes with frailty; it is a progressive decline in balance, mobility and strength. As people grow older, voluntary physical activity tends to decline, which is closely associated with reduced aerobic capacity, muscle strength and stamina. In recent years, researchers highlighted that regular physical exercise may help prevent frailty (Liu & Fielding, 2011). Chen et al. (2014), emphasized that the early detection of this fragility, together with timely evaluation and treatment, is central to delivering high-quality care for the expanding elderly population.

There is consistent evidence that structured exercise programs can lower both the number of falls and the incidence of individuals who experience them. The most effective strategies are multicomponent interventions that combine balance and strength training. Enhanced muscle activation, together with a reduction in the fear of falling, likely contributes to better functional outcomes, such as improved performance on the Timed Up and Go (TUG) test (Patar & Scheicher, 2014).

Previous studies have shown that increasing ankle mobility through different forms of physical activity, such as stretching, water exercise and Tai Chi may have some benefits in increasing balance in older people (Menz et al., 2005).

The slow, deliberate movements of Tai Chi Chuan enhance focus and attention, promoting a sense of calm and relaxation even in stressful situations. Evidence from research indicates that practicing Tai Chi Chuan can significantly improve balance and reduce fear of falling among community-dwelling older adults (Hosseini et al., 2018).

The purpose of this study was to examine how a structured exercise program that integrates balance, strength, and coordination activities influences postural control in older adults. To capture these effects, center-of-pressure parameters—such as area, path length, and velocity—were measured on a baropodometric platform under different testing conditions, bipedalism and half-squat position with eyes open and closed, each once on hard and then on soft surfaces.

MATERIAL AND METHODS

Participants

Four community-dwelling older adults (two men and two women) participated in the 6-week study. The participants' ages ranged from 72 to 94 years (M = 79.0, SD = 9.9). The mean height was 167.0 cm (SD = 8.9), and the mean weight was 69.5 kg (SD = 16.1). All participants were able to ambulate independently without assistive devices and reported no acute musculoskeletal or neurological conditions that would limit their ability to participate in the exercise program.

The study was conducted in accordance with the ethical standards of the Declaration of Helsinki (World Medical Association, 2013).

All participants received a detailed explanation of the purpose, procedures, potential risks, and benefits of the study. Written informed consent was obtained from each participant prior to enrollment. Participants were informed of their right to withdraw from the study at any time without any consequences.

Procedure

Evaluation protocols

The evaluation was conducted once for each of the following protocols, each lasting 15 seconds. The subject assumed a bipodal orthostatic position with feet at shoulder width. The protocols were:

- Standing on a baropodometric plate (H) with eyes closed (EC).
- Standing on a baropodometric plate (H) with eyes open (EO).
- Standing on a baropodometric plate (H) covered with a 1.5 cm thick sponge (S), with eyes closed (EC).
- Standing on a baropodometric plate (H) covered with a 1.5 cm thick sponge (S), with eyes open (EO).

- In a half-squat position on the baropodometric plate (H) with arms extended forward and eyes open (EO).
- In a half-squat position on the baropodometric plate (H) with arms extended forward and eyes closed (EC).

The sequence allowed the subject to adapt to varying orthostatic positions. The half-squat was maintained for 15 seconds outside the orthostatic balance zone, enabling the evaluation of aerobic capacity while ensuring safety.

The Romberg test, typically performed with eyes open (EO) and eyes closed (EC) on a hard surface (H), was expanded to include new conditions: evaluation on a soft surface (S) and in a half-squat position (H-Sqt). The following parameters were evaluated:

- Soft Surface (S): Eyes closed (EC) and open (EO) measurements for barycenter area, length, and speed (left foot, right foot and body).
- Hard Surface (H): Eyes closed (EC) and open (EO) measurements for barycenter area, length, and speed (left foot, right foot and body), both in the standing and half-squat positions.

The assessments were conducted using the BTS P-WALK baropodometric platform, which consists of a 675x540x5 mm plate equipped with 2,304 resistive sensors (1x1 cm each), with a pressure range of 30-400 kPa, a sampling frequency of 100 Hz, and an AC/USB adapter power supply, weighing approximately 7 kg.

Materials

Each training session was performed three times per week, lasted 20–25 minutes at a low-to-moderate intensity, and was structured into three phases: a 5-minute warm-up (seated mobility exercises), 15 minutes of progressive balance and strengthening exercises, and a 3–5-minute cool-down with breathing and relaxation exercises.

Table 1. Exercise program

Exercise type	Objectives	Progression
Static isometric	Improving static balance through postural muscle activation	Hard surface versus unstable, eyes open versus closed
Dynamic balance	Increasing dynamic stability and walking safety	Simple walking versus over obstacle
Strength	Development of lower body and core muscle strength	Increasing elastic band resistance and the number of repetitions

Exercise type	Objectives	Progression
Proprioceptive and sensory system training	Proprioception, vestibular and visual control stimulation	Hard surface versus unstable
Functional (ADL-based)	Adapting exercises into ADL	Hand support versus no hand support
Coordination and stretching	Improvement of coordination and flexibility	Task complexity through interactive games

Data analysis

All statistical analyses were performed using IBM SPSS Statistics (Version XX; IBM Corp., Armonk, NY, USA). Descriptive statistics (means and standard deviations) were calculated for all 36 force-platform variables at the three measurement time points (initial, intermediate and final). Data were first screened for normality using the Shapiro–Wilk test. Although most variables were approximately normally distributed, several variables showed significant departures from normality ($p < .05$). Given the small sample size ($N = 4$) and the presence of non-normally distributed variables, a nonparametric approach was selected for inferential analysis.

To compare repeated measures across the three time points, Friedman's test was conducted for each variable. This test is the nonparametric alternative to repeated-measures ANOVA and evaluates whether the median ranks differ across related samples. When significant main effects were observed, post hoc pairwise comparisons were planned using Wilcoxon signed-rank tests with Bonferroni correction to control for Type I error. No significant Friedman tests were found, so post hoc tests were not performed. The level of significance was set at $p = .05$ for all tests.

RESULTS

The distribution of each variable at all three time points (initial, intermediate, and final) was examined using the Shapiro–Wilk test. Most variables were normally distributed ($p > .05$), suggesting approximate normality. However, several variables—including H_EC_LSF at baseline ($p = .017$), INTERIM_S_EO_LSF ($p = .017$), INTERIM_H_EO_Aria_R_HalfSquat ($p = .030$), and FINAL_H_EO_Aria_B ($p = .012$)—significantly deviated from normality. Given the very small sample size ($N = 4$), even minor departures from normality could bias parametric analyses.

To ensure a conservative and robust analysis, we therefore used Friedman's test, the nonparametric equivalent of repeated-measures ANOVA, which does not require normally distributed data and is suitable for comparing three related measurements within subjects.

Table 2. Friedman Test results for variables obtained in the upright position on a hard surface with eyes open

Pair	Variable Name	N	Mean	Std. Deviation	Minimum	Maximum	Friedman Test (p)
	H_EO_Aria_L	4	10.23	4.39	6.1	15.65	
1	INTERIM_H_EO_Aria_L	4	9.6	6.22	2.28	15.43	0.779
	FINAL_H_EO_Aria_L	4	9.12	10.06	1.35	23.5	
	H_EO_Aria_B	4	47.48	29.1	18.14	85.47	
2	INTERIM_H_EO_Aria_B	4	19.27	11.92	10.2	36.61	0.105
	FINAL_H_EO_Aria_B	4	22.4	12.89	14.73	41.68	
	H_EO_Aria_R	4	16.1	11.2	4.78	28.44	
3	INTERIM_H_EO_Aria_R	4	6.8	2.85	4.25	10.04	0.174
	FINAL_H_EO_Aria_R	4	5.73	1.93	3.57	8.26	
	H_EO_L	4	91.35	27.17	60.7	118.9	
4	INTERIM_H_EO_L	4	86.4	11.6	74.4	99.2	0.779
	FINAL_H_EO_L	4	76.6	23.07	49.3	96.9	
	H_EO_Vit	4	6.08	1.83	4	7.9	
5	INTERIM_H_EO_Vit	4	5.78	0.75	5	6.6	0.779
	FINAL_H_EO_Vit	4	5.13	1.54	3.3	6.5	
	H_EO_LSF	4	2.28	0.78	1.4	3.3	
6	INTERIM_H_EO_LSF	4	5.83	3.27	2.2	9.7	0.105
	FINAL_H_EO_LSF	4	3.95	1.87	2.3	6.6	

(mm^2) = millimiter square; mm (millimeter); (mm/s) millimeter/seconds; SD = standard deviation; Hard surface Eyes Open Area Left (H_EO_Area_L, mm^2); Interim Hard surface Eyes Open Area Left (Interim_H_EO_Area_L, mm^2); Final Hard surface Eyes Open Area Left (Final_H_EO_Area_L, mm^2); Hard surface Eyes Open Area Body (H_EO_Area_B, mm^2); Interim Hard surface Eyes Open Area Body (Interim_H_EO_Area_B, mm^2); Final Hard surface Eyes Open Area Body (Final_H_EO_Area_B, mm^2); Hard surface Eyes Open Area Right (H_EO_Area_R, mm^2); Interim Hard surface Eyes Open Area Right (Interim_H_EO_Area_R, mm^2); Final Hard surface Eyes Open Area Right (Final_H_EO_Area_R, mm^2); Hard surface Eyes Open Length (H_EO_L, mm); Interim Hard surface Eyes Open Length (Interim_H_EO_L, mm); Final Hard surface Eyes Open Length (Final_H_EO_L, mm); Hard surface Eyes Open Speed (H_EO_Vit, mm/s), Interim Hard surface Eyes Open Speed (Interim_H_EO_Vit, mm/s); Final Hard surface Eyes Open Speed (Final_H_EO_Vit, mm/s); Hard surface Eyes Open LSF (H_EO_LSF); Interim Hard surface Eyes Open LSF (Interim_H_EO_LSF); Final Hard surface Eyes Open LSF (Final_H_EO_LSF).

Table 3. Friedman Test results for variables obtained in the upright position on a soft surface with eyes open

Pair	Variable Name	N	Mean	Std. Deviation	Minimum	Maximum	Friedman Test (p)
	S_EO_Aria_L	4	12.34	10.61	2.46	27.07	
1	INTERIM_S_EO_Aria_L	4	37.56	29.32	4.92	75.3	0.174
	FINAL_S_EO_Aria_L	4	33.27	18.36	11.85	55.98	
	S_EO_Aria_B	4	91.55	41.28	43.43	141.06	
2	INTERIM_S_EO_Aria_B	4	151.49	97.54	15.01	242.32	0.472
	FINAL_S_EO_Aria_B	4	122.09	60.4	51.11	176.17	
	S_EO_Aria_R	4	30.09	27.79	3.43	65.97	
3	INTERIM_S_EO_Aria_R	4	27.13	27.37	3.11	66.27	0.472
	FINAL_S_EO_Aria_R	4	19.32	12.89	11.08	38.51	
	S_EO_L	4	99.95	20.22	74	120.3	
4	INTERIM_S_EO_L	4	104.58	30.84	64.9	134.3	0.779
	FINAL_S_EO_L	4	116.78	20.42	92	141.6	
	S_EO_Vit	4	6.33	1.61	4.9	8	
5	INTERIM_S_EO_Vit	4	6.98	2.09	4.3	9	0.282
	FINAL_S_EO_Vit	4	7.78	1.36	6.1	9.4	
	S_EO_LSF	4	1.53	0.28	1.2	1.8	
6	INTERIM_S_EO_LSF	4	1.55	1.84	0.4	4.3	0.42
	FINAL_S_EO_LSF	4	1.2	0.79	0.5	2.3	

(mm^2) = millimiter square; mm (millimeter); (mm/s) millimeter/seconds; SD = standard deviation; Soft surface Eyes Open Arial Left (S_EO_Aria_L, mm^2); Interim Soft surface Eyes Open Arial Left (Interim_S_EO_Aria_L, mm^2); Final Soft surface Eyes Open Arial Left (Final_S_EO_Aria_L, mm^2); Soft surface Eyes Open Arial Body (S_EO_Aria_B, mm^2); Interim Soft surface Eyes Open Arial Body (Interim_S_EO_Aria_B, mm^2); Final Soft surface Eyes Open Arial Body (Final_S_EO_Aria_B, mm^2); Soft surface Eyes Open Arial Right (S_EO_Aria_R, mm^2); Interim Soft surface Eyes Open Arial Right (S_EO_Aria_R, mm^2); Final Soft surface Eyes Open Arial Right (S_EO_Aria_R, mm^2); Soft surface Eyes Open Lenght (S_EO_L, mm); Interim Soft surface Eyes Open Lenght (Interim_S_EO_L, mm); Final Soft surface Eyes Open Lenght (Final_S_EO_L, mm); Soft surface Eyes Open Speed (S_EO_Vit, mm/s); Interim Soft surface Eyes Open Speed (Interim_S_EO_Vit, mm/s); Final Soft surface Eyes Open Speed (Final_S_EO_Vit, mm/s); Soft surface Eyes Open LSF (S_EO_LSF); Interim Soft surface Eyes Open LSF (Interim_S_EO_LSF); Final Soft surface Eyes Open LSF (Final_S_EO_LSF).

Table 4. Friedman Test results for variables obtained in the upright position on a hard surface with eyes close

Pair	Variable Name	N	Mean	Std. Deviation	Minimum	Maximum	Friedman Test (p)
	H_EC_Arial_L	4	9.68	6.74	3.01	17.41	
1	INTERIM_H_EC_Aria_L	4	19.35	20.16	0.71	44.41	0.779
	FINAL_H_EC_Aria_L	4	17.45	15.84	0.76	34.12	
	H_EC_Aria_B	4	52.89	36.74	6.1	95.9	
2	INTERIM_H_EC_Aria_B	4	92.32	90.33	6.74	173.09	0.472
	FINAL_H_EC_Aria_B	4	59.96	67.66	5.72	158.74	
	H_EC_Aria_R	4	21.68	19.35	4.57	49.33	
3	INTERIM_H_EC_Aria_R	4	15.36	15.07	2.36	33.79	0.779
	FINAL_H_EC_Aria_R	4	17.32	25.67	1.82	55.72	
	H_EC_L	4	114.88	55.79	65.4	186.7	
4	INTERIM_H_EC_L	4	110.9	52.07	56.4	167.1	1
	FINAL_H_EC_L	4	136.18	113.38	45.7	302.1	
	H_EC_Vit	4	7.65	3.68	4.4	12.4	
5	INTERIM_H_EC_Vit	4	7.38	3.44	3.8	11.1	1
	FINAL_H_EC_Vit	4	9.05	7.55	3	20.1	
	H_EC_LSF	4	4.1	4.42	1.4	10.7	
6	INTERIM_H_EC_LSF	4	3.45	3.54	0.8	8.4	0.779
	FINAL_H_EC_LSF	4	3.8	2.83	1.9	8	

(mm^2) = millimiter square; mm (millimeter); (mm/s) millimeter/seconds; SD = standard deviation; Hard surface Eyes Close Arial Left (H_EC_Aria_L); Interim Hard surface Eyes Close Arial Left (Interim_ H_EC_Aria_L, mm^2); Final Hard surface Eyes Close Arial Left (Final_H_EC_Aria_L, mm^2); Hard surface Eyes Close Arial Body (H_EC_Aria_B, mm^2); Interim Hard surface Eyes Close Arial Body (Interim_H_EC_Aria_B, mm^2); Final Hard surface Eyes Close Arial Body (Final_ H_EC_Aria_B, mm^2); Hard surface Eyes Close Arial Right (H_EC_Aria_R, mm^2); Interim Hard surface Eyes Close Arial Right (Interim_H_EC_Aria_R, mm^2); Final Hard surface Eyes Close Arial Right (Final_H_EC_R, mm^2); Hard surface Eyes Close Lenght (H_EC_L, mm); Interim Hard surface Eyes Close Lenght (Interim_H_EC_L, mm); Final Hard surface Eyes Close Lenght (Final_H_EC_L, mm); Hard surface Eyes Close Speed (H_EC_Vit, mm/s); Interim Hard surface Eyes Close Speed (Interim_H_EC_Vit, mm/s); Final Hard surface Eyes Close Speed (Final_H_EC_Vit, mm/s); Hard surface Eyes Close LSF (H_EC_LSF); Interim Hard surface Eyes Close LSF (Interim_H_EC_LSF); Final Hard surface Eyes Close Speed (Final_H_EC_LSF).

Table 5. Friedman Test results for variables obtained in the upright position on a soft surface with eyes close

Pair	Variable Name	N	Mean	Std. Deviation	Minimum	Maximum	Friedman Test (p)
	S_EC_Aria_L	4	23.9	13.67	11.64	38.24	
1	INTERIM_S_EC_Aria_L	4	14.66	3.63	10.79	19.17	0.368
	FINAL_S_EC_Aria_L	4	44.47	37.82	7.41	97.24	
	S_EC_Aria_B	4	108.21	44.49	64.17	164.9	
2	INTERIM_S_EC_Aria_B	4	94.65	36.14	62	143.67	0.472
	FINAL_S_EC_Aria_B	4	161.96	114.82	48.84	311.63	
	S_EC_Aria_R	4	29.61	14.95	10.44	44.6	
3	INTERIM_S_EC_Aria_R	4	15.95	7.78	9.42	27.24	0.779
	FINAL_S_EC_Aria_R	4	35.37	40.92	7.02	95.83	
	S_EC_L	4	154.63	53.56	90.4	216	
4	INTERIM_S_EC_L	4	106.45	18.87	87.5	132.1	0.174
	FINAL_S_EC_L	4	144.8	54.74	88.7	215.1	
	S_EC_Vit	4	10.3	3.59	6	14.4	
5	INTERIM_S_EC_Vit	4	7.08	1.27	5.8	8.8	0.174
	FINAL_S_EC_Vit	4	9.63	3.64	5.9	14.3	
	S_EC_LSF	4	2.48	1.34	1.3	4.4	
6	INTERIM_S_EC_LSF	4	1.28	0.54	0.6	1.8	0.165
	FINAL_S_EC_LSF	4	1.28	0.81	0.4	2.1	

(mm^2) = millimiter square; mm (millimeter); (mm/s) millimeter/seconds; SD = standard deviation; Soft surface Eyes Close Arial Left (S_EC_Aria_L, mm^2); Interim Soft surface Eyes Close Arial Left (Interim_S_EC_Aria_L, mm^2); Final Soft surface Eyes Close Arial Left (Final_S_EC_Aria_L, mm^2); Soft surface Eyes Close Arial Body (S_EC_Aria_B, mm^2); Interim Soft surface Eyes Close Arial Body (Interim_S_EC_Aria_B, mm^2); Final Soft surface Eyes Close Arial Body (Final_S_EC_Aria_B, mm^2); Soft surface Eyes Close Arial Right (S_EC_Aria_R, mm^2); Interim Soft surface Eyes Close Arial Right (Interim_S_EC_Aria_R, mm^2); Final Soft surface Eyes Close Arial Right (Final_S_EC_Aria_R, mm^2); Soft surface Eyes Close Lenght (S_EC_L, mm); Interim Soft surface Eyes Close Lenght (Interim_S_EC_L, mm); Final Soft surface Eyes Close Lenght (Final_S_EC_L, mm); Soft surface Eyes Close Speed (S_EC_Vit, mm/s); Interim Soft surface Eyes Close Speed (Interim_S_EC_Vit, mm/s); Final Soft surface Eyes Close Speed (Final_S_EC_Vit, mm/s); Soft surface Eyes Close LSF (S_EC_LSF); Interim Soft surface Eyes Close LSF (Interim_S_EC_LSF); Final Soft surface Eyes Close LSF (Final_S_EC_LSF).

Table 6. Friedman Test results for variables obtained in the HalfSquat position on a hard surface with eyes open

Pair	Variable Name	N	Mean	Std. Deviation	Minimum	Maximum	Friedman Test (p)
	H_EO_Aria_L_HalfSquat	4	40.47	21.84	12.48	57.92	
1	INTERIM_H_EO_Aria_L_HalfSquat	4	64.15	33.71	17.04	96.81	0.174
	FINAL_H_EO_Aria_L_HalfSquat	4	55.5	49.91	10.44	126.55	
	H_EO_Aria_B_HalfSquat	4	159.41	119.14	34.43	318.8	
2	INTERIM_H_EO_Aria_B_HalfSquat	4	133.41	56.99	49.31	169.91	0.472
	FINAL_H_EO_Aria_B_HalfSquat	4	197.08	146.5	86.83	412.88	
	H_EO_Aria_R_HalfSquat	4	33.67	19.92	5.51	52.41	
3	INTERIM_H_EO_Aria_R_HalfSquat	4	36.39	18.17	9.46	47.38	0.368
	FINAL_H_EO_Aria_R_HalfSquat	4	39.14	16.72	16.1	54.17	
	H_EO_L_HalfSquat	4	159.08	63.81	65.6	20.8	
4	INTERIM_H_EO_L_HalfSquat	4	149.48	62.43	65	215.5	0.779
	FINAL_H_EO_L_HalfSquat	4	153.73	54.43	77.3	205.9	
	H_EO_Vit_HalfSquat	4	10.6	4.23	4.4	13.9	
5	INTERIM_H_EO_Vit_HalfSquat	4	9.95	4.19	4.3	14.4	0.627
	FINAL_H_EO_Vit_HalfSquat	4	10.25	3.6	5.2	13.7	
	H_EO_LSF_HalfSquat	4	1.33	0.59	0.6	1.9	
6	INTERIM_H_EO_LSF_HalfSquat	4	1.15	0.19	0.9	1.3	0.282
	FINAL_H_EO_LSF_HalfSquat	4	0.93	0.31	0.5	1.2	

(mm^2) = millimiter square; mm (millimeter); (mm/s) millimeter/seconds; SD = standard deviation; Hard surface Eyes Open Arial Left HalfSquat (H_EO_Aria_L_HalfSquat, mm^2); Interim Hard surface Eyes Open Arial Left HalfSquat (Interim_H_EO_Aria_L_HalfSquat, mm^2); Final Hard surface Eyes Open Arial Left HalfSquat (Final_H_EO_Aria_L_HalfSquat, mm^2); Hard surface Eyes Open Arial Body HalfSquat (H_EO_Aria_B_HalfSquat, mm^2); Interim Hard surface Eyes Open Arial Body HalfSquat (Interim_H_EO_Aria_B_HalfSquat, mm^2); Final Hard surface Eyes Open Arial Body HalfSquat (Final_H_EO_Aria_B_HalfSquat, mm^2); Hard surface Eyes Open Arial Right HalfSquat (H_EO_Aria_R_HalfSquat, mm^2); Interim Hard surface Eyes Open Arial Right HalfSquat (Interim_H_EO_Aria_R_HalfSquat, mm^2); Final Hard surface Eyes Open Arial Right HalfSquat (Final_H_EO_Aria_R_HalfSquat, mm^2); Hard surface Eyes Open Lenght HalfSquat (H_EO_L_HalfSquat, mm); Interim Hard surface Eyes Open Lenght HalfSquat (Interim_H_EO_L_HalfSquat, mm); Final Hard surface Eyes Open Lenght HalfSquat (Final_H_EO_L_HalfSquat, mm); Hard surface Eyes Open Speed HalfSquat (H_EO_Vit_HalfSquat, mm/s); Interim Hard surface Eyes Open Speed HalfSquat (Interim_H_EO_Vit_HalfSquat, mm/s); Final Hard surface Eyes Open Speed HalfSquat (Final_H_EO_Vit_HalfSquat, mm/s); Hard surface Eyes Open LSF HalfSquat (H_EO_LSF_ HalfSquat); Interim Hard surface Eyes Open LSF HalfSquat (Interim_H_EO_LSF_ HalfSquat); Final Hard surface Eyes Open LSF HalfSquat (Final_H_EO_LSF_ HalfSquat).

Table 7. Friedman Test results for variables obtained in the HalfSquat position on a hard surface with eyes close

Pair	Variable Name	N	Mean	Std. Deviation	Minimum	Maximum	Friedman Test (p)
	H_EC_Aria_L_HalfSquat	4	77.86	39.71	39.51	133.61	
1	INTERIM_H_EC_Aria_L_HalfSquat	4	172.15	66.79	128.86	271.08	0.174
	FINAL_H_EC_Aria_L_HalfSquat	4	160.22	121.26	16.89	269.14	
	H_EC_Aria_B_HalfSquat	4	261.63	122.24	98.65	390.36	
2	INTERIM_H_EC_Aria_B_HalfSquat	4	505.83	87.56	418.73	627.33	0.368
	FINAL_H_EC_Aria_B_HalfSquat	4	559.09	493.28	84.06	1213.65	
	H_EC_Aria_R_HalfSquat	4	61.96	50.21	13.81	120.97	
3	INTERIM_H_EC_Aria_R_HalfSquat	4	134.26	135.87	54.97	336.7	0.174
	FINAL_H_EC_Aria_R_HalfSquat	4	99.17	58.65	27.23	170.82	
	H_EC_L_HalfSquat	4	237.95	108.93	105.4	363.5	
4	INTERIM_H_EC_L_HalfSquat	4	264.83	111.85	132.2	392.7	0.368
	FINAL_H_EC_L_HalfSquat	4	234.65	110.35	81.1	344	
	H_EC_Vit_HalfSquat	4	15.85	7.25	7	24.2	
5	INTERIM_H_EC_Vit_HalfSquat	4	17.65	7.46	8.8	26.2	0.368
	FINAL_H_EC_Vit_HalfSquat	4	15.63	7.35	5.4	22.9	
	H_EC_LSF_HalfSquat	4	0.93	0.13	0.8	1.1	
6	INTERIM_H_EC_LSF_HalfSquat	4	0.53	0.21	0.3	0.8	0.174
	FINAL_H_EC_LSF_HalfSquat	4	0.7	0.48	0.2	1.2	

(mm^2) = millimiter square; mm (millimeter); (mm/s) millimeter/seconds; SD = standard deviation; Hard surface Eyes Close Arial Left HalfSquat (H_EC_Aria_L_ HalfSquat, mm^2); Interim Hard surface Eyes Close Arial Left HalfSquat (Interim_H_EC_Aria_L_ HalfSquat, mm^2); Final Hard surface Eyes Close Arial Left HalfSquat (Final_H_EC_Aria_L_ HalfSquat, mm^2); Hard surface Eyes Close Arial Body HalfSquat (H_EC_Aria_B_ HalfSquat, mm^2); Interim Hard surface Eyes Close Arial Body HalfSquat (Interim_H_EC_Aria_B_ HalfSquat, mm^2); Final surface Eyes Close Arial Body HalfSquat (Final_H_EC_Aria_B_ HalfSquat, mm^2); Hard surface Eyes Close Arial Right HalfSquat (H_EC_Aria_R_ HalfSquat, mm^2); Interim Hard surface Eyes Close Arial Right HalfSquat (Interim_H_EC_Aria_R_ HalfSquat, mm^2); Final Hard surface Eyes Close Arial Right HalfSquat (Final_H_EC_Aria_R_ HalfSquat, mm^2); Hard surface Eyes Close Lenght HalfSquat (H_EC_L_ HalfSquat, mm); Interim Hard surface Eyes Close Lenght HalfSquat (Interim_H_EC_L_ HalfSquat, mm); Final Hard surface Eyes Close Lenght HalfSquat (Final_H_EC_L_ HalfSquat, mm); Hard surface Eyes Close Speed HalfSquat (H_EC_Vit_ HalfSquat, mm/s); Interim Hard surface Eyes Close Speed HalfSquat (Interim_H_EC_Vit_ HalfSquat, mm/s); Final Hard surface Eyes Close Speed HalfSquat (Final_H_EC_Vit_ HalfSquat, mm/s); Hard surface Eyes Close LSF HalfSquat (H_EC_LSF_ HalfSquat); Interim Hard surface Eyes Close LSF HalfSquat (Interim_H_EC_LSF_ HalfSquat); Final Hard surface Eyes Close LSF HalfSquat (Final_H_EC_LSF_ HalfSquat).

To evaluate potential changes across three measurement sessions (initial, intermediate, final), Friedman's tests were performed separately for 36 force-platform variables. The analyses revealed no statistically significant differences across time for any of the variables, $\chi^2(2)$ range = 0.00–4.50, all $p \geq .105$. This indicates that, within this small sample, the distributions of these measurements did not differ significantly across sessions.

For example, several measures of sway area (e.g., H_EO_Aria_B, S_EO_Aria_B, H_EC_Aria_B_HalfSquat) decreased slightly, while others showed mild increases.

H_EO_Aria_L, H_EO_Aria_B, H_EO_Aria_R:

Mean values for the eyes-open area variables showed slight decreases from initial to intermediate measurements, followed by small rebounds at the final measurement.

H_EO_L, H_EO_Vit, H_EO_LSF:

These parameters (related to sway path length and velocity) exhibited subtle reductions across time.

H_EC_Aria_L, H_EC_Aria_B, H_EC_Aria_R, H_EC_L, H_EC_Vit, H_EC_LSF: With eyes closed, area and velocity measures showed mixed trends, some increasing slightly.

S_EO and S_EC Variables:

Under semitandem stance, COP areas and velocities followed similar patterns, with moderate fluctuations but no clear directional change.

Half-Squat Conditions (H_EO_Aria_L_HalfSquat, H_EO_Aria_B_HalfSquat, etc.):

In half-squat postures, several variables showed decreases in mean sway area and path length by the final assessment.

DISCUSSION

The present study aimed to investigate the effects of a multicomponent balance and strength training program on postural control in older adults, using force-platform parameters. Thirty-six variables reflecting center-of-pressure (COP) behavior, surface area, velocity and other kinetic indicators were assessed at three time points: initial, intermediate and final. Friedman's nonparametric tests indicated no statistically significant differences across time for any variables (all

$p \geq .105$). Nonetheless, descriptive analyses revealed meaningful patterns in the evolution of mean values that merit discussion in light of the intervention content.

Across most variables, mean values exhibited small-to-moderate directional changes from baseline to final assessment, often aligning with expected physiological adaptations following balance and strength training. This might indicate enhanced exploration of the base of support or increased confidence in maintaining balance. Our found mixed responses are consistent with previous research showing that older adults may initially display greater sway during early stages of training, due to increased motor strategy variability, followed by stabilization as training progresses.

Eyes-open area variables showed slight decreases. This could reflect early improvements in steadiness after the first few training sessions, with a plateau effect towards the end of the program. Given that many exercises challenged static stance (narrow base of support, surface perturbations), such changes align with improved control of mediolateral sway.

A lower COP velocity is suggestive of a more economical postural control, often interpreted as more efficient balance maintenance. Although nonsignificant, this trend is compatible with the focus on core and lower-limb strengthening and dynamic stability exercises included in the program (e.g., heel-to-toe walking, sit-to-stand transitions, obstacle crossing).

On the other hand, area and velocity measures showed mixed trends. Training on unstable surfaces and with visual deprivation encouraged participants to rely more on proprioceptive and vestibular inputs, which might initially increase sway, but ultimately enhance sensory reweighting. The lack of consistent decreases may be attributable to the short duration of the program and small sample size.

Under half-squat stance, COP areas and velocities followed similar patterns, with moderate fluctuations but no clear directional change. These findings may suggest that the half-squat stance remained challenging for participants throughout the intervention, as well as training mediolateral stability in older adults. For further proof, longer interventions are needed.

Half-squat tasks demand greater muscular engagement and postural control, so it is noteworthy that several variables also showed decreases in mean sway area and path length. The intervention included functional lower-limb strengthening (e.g., mini-squats, sit-to-stand, step-ups), which may have contributed to improved stability in this position, despite the absence of statistical significance.

While the absence of statistically significant findings prevents firm conclusions, the directionality of the observed changes supports the potential utility of multicomponent exercise programs for enhancing postural control in older adults. The small sample size (N=4) likely limited statistical power, increasing the risk of Type II error. Effect size estimation (e.g., Kendall's W) and visual inspection of mean changes suggest that some variables may have clinically relevant improvements that warrant further exploration in larger cohorts.

Importantly, the training program progressively integrated static, dynamic and dual-task balance challenges, while targeting proprioceptive, vestibular and visual components of postural control. Even in the absence of significant improvements, maintaining postural stability over time is itself a positive outcome, as age-related decline would be expected without intervention.

Similar to our findings, Chittrakul et al. (2020) reported no statistically significant differences following a multicomponent balance and strength program. Yet descriptive trends suggested modest improvements in sway area and postural stability. This supports the idea that even in the absence of strong statistical outcomes, short-term exercise interventions may help maintain or slightly improve balance in older adults.

Antúnez et al. (2020), unlike other rehabilitation interventions, demonstrated that a specific proprioceptive protocol can generate clinically relevant improvements in physical performance, although its long-term efficacy remains to be established.

Our results, despite not statistically significant, are consistent with the findings of Leandri et al. (2015), who demonstrated that anterior–posterior sway with eyes closed is significantly associated with cognitive performance in older adults. This supports the idea that vestibular and sensory mechanisms play a crucial role in maintaining postural stability.

Sustaining balance capacity over time, even without marked improvements, is clinically valuable because age is typically accompanied by progressive decline. Yoon et al. (2019) also highlighted that balance impairments tend to emerge at early stages, suggesting that timely interventions are essential for preserving mobility and lowering fall risk.

The primary limitation of this study is the very small sample size, which limits statistical power. Additionally, the short intervention duration (6 weeks) may not have been sufficient to elicit robust adaptations in postural control. Future research should replicate these findings with a larger sample, a control group and longer follow-up to assess retention of training effects. Including measures of functional performance (e.g., Timed Up and Go, gait speed) may also help link force-platform metrics to clinically meaningful outcomes.

CONCLUSIONS

The present study explored the effects of a multicomponent exercise program targeting balance, strength, and coordination on postural control in older adults. Although Friedman's tests did not reveal statistically significant differences across the three measurement time points for any of the 36 variables. Descriptive trends suggested modest improvements in sway area, path length, and velocity measures—particularly under eyes-open and half-squat conditions. These results indicate that even a relatively short, low-to-moderate intensity intervention may help maintain or slightly improve postural stability in older adults, which is clinically relevant for fall prevention.

The lack of statistically significant findings is likely attributable to the small sample size and limited power, underscoring the need for larger-scale studies with longer follow-up periods. Future research should confirm these preliminary findings, explore dose–response relationships of balance and strength training, and investigate whether improvements in force-platform parameters translate into meaningful reductions in fall risk and functional disability.

AUTHOR CONTRIBUTIONS

Author 1 contributed to the analysis of the results and writing of the manuscript, author 2 and author 3 contributed to the design and implementation of the research. Author 4 supervised the research project, provided guidance during all stages of the study, and critically reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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CRITICAL CONSIDERATIONS ON THE SINGLE VERTICAL JUMP TEST AS AN INDICATOR OF LOWER-LIMB POWER: PRELIMINARY FINDINGS

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ABSTRACT. *Introduction*: The vertical jump test (VJT) is widely used to estimate lower-limb power through predictive equations, but the theoretical validity of these models remains uncertain. *Objective:* This preliminary study aimed to compare three predictive equations (Lewis, Harman, Johnson & Bahamonde) for estimating average lower-limb power from VJT, focusing on discrepancies in outcomes and theoretical validity. *Material and Methods*: Five healthy male students (age 20.2 ± 0.2 years; height 178.6 ± 4.72 cm; body mass 73.0 ± 8.12 kg) performed countermovement jumps (CMJ) measured with the OptoJump system, with the best trial retained for analysis. Average power was calculated using the three predictive equations. Descriptive statistics (M ± SD) were computed, and differences between models were analyzed with the Friedman test. Effect size was quantified with Kendall's W. *Results*: Significant differences were found between formulas (χ^2 (2) = 10.000, p = 0.007, W = 0.67, large effect). The Johnson & Bahamonde model yielded the highest values, followed by Harman and Lewis. None of the equations demonstrated dimensional homogeneity. *Discussion:* Findings highlight systematic discrepancies between predictive models, raising concerns about their reliability in practice. The lack of dimensional consistency undermines the theoretical validity of these equations, despite their continued use in applied settings. Consequently, classification of athletes based solely on these formulas may be misleading. *Conclusions:* Predictive equations for estimating lower-limb power from vertical jumps produce inconsistent results and fail to satisfy dimensional homogeneity. Future approaches should integrate time-dependent variables to ensure biomechanical validity and reliability.

Keywords: vertical jump; lower-limb power; sport assessment; athletic performance; predictive models; countermovement jump

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INTRODUCTION

Vertical jumping is a fundamental motor skill that integrates multiple neuromuscular qualities into a single explosive action. For this reason, the vertical jump test (VJT) is widely used in sport and exercise science to assess lower-limb function (Öncen et al., 2018; Sánchez-Sixto et al., 2021; Cooper et al.;2020; Santa et al., 2025). It remains popular among coaches, physical education & sport teachers, strength and conditioning specialists, and researchers because it is simple, practical, and applicable in both performance and health contexts (Keir et al., 2003; Milo et al., 2017; Stupar et al., 2020; Graur & Șanta-Moldovan, 2024).

Historically, the first standardized procedure was introduced by Sargent (1921) and later redefined by Abalakov in the 1938 (Klavora, 2000). With advances in technology, instruments such as force platform, motion capture, and optical systems have provided more detailed biomechanical information (Yingling et al., 2018; Buscemi et al., 2019, Geantă & de Hillerin, 2023). However, in applied settings, jump height remains the most common outcome (Sánchez-Sixto et al., 2018). Recent studies highlight that jump performance is influenced by multiple biomechanical and morphological factors beyond simple jump height, such as limb alignment, body composition, and eccentric force capacity (Daugherty et al., 2021; Vaverka et al., 2016; Nishiumi et al., 2023).

To extend its utility, several predictive equations have been proposed to estimate lower limb power from jump height and basic anthropometric data (Fox & Mathews, 1974; Harman et al., 1991; Johnson & Bahamonde, 1996; Sayers et al., 1999). These models are still widely cited and even embedded in online calculators (Mackenzie, 2007). Their appeal lies in their simplicity, but important methodological issues remain.

First, the term power is often used inconsistently, referring to athletic performance, rather than its mechanical definition. Power is mechanically defined as the rate of doing work overtime (Knudson, 2009; Hall, 2021). Second, most equations exclude time as a variable, which leads to dimensional inconsistencies and undermines their validity (Nettles, 2022). Consequently, different formulas yield substantially different values, which may not reflect true mechanical power.

Several investigations support this critique, showing that predictive equations often fail to appropriately categorize athletes (Ache-Dias et al., 2016), produce inconsistent rankings (Lara-Sánchez et al., 2011), or confound body size with actual muscle power output (Markovic et al., 2014). Furthermore, comparative analyses demonstrate discrepancies between calculation methods for jump height (Xu et al., 2023) and emphasize that power predictions vary depending on the model and population studied (Canavan & Vescovi, 2004; Amonette et al., 2012; Gomez-Bruton et al., 2019; Duncan et al., 2013).

This gap between the popularity of VJT-based estimates and their biomechanical limitations requires critical examination. Few studies have directly predictive equations under controlled conditions (Canavan & Vescovi, 2004; Duncan, Lyons, & Nevill, 2008; Amonette et al., 2012; Wright et al., 2012), and even fewer addressed their theoretical inconsistencies (Markovic et al., 2014; Xu et al., 2023; Eythorsdottir et al., 2024).

The purpose of this preliminary investigation was to analyze three popular predictive equations – Lewis, Harman, and Johnson & Bahamonde, commonly used for estimating lower-limb power. The study focused on identifying discrepancies between the results provided by these formulas and evaluating whether they comply with the principle of dimensional homogeneity of measurement units.

MATERIAL AND METHODS

This study employed a preliminary, cross-sectional design with a within-subjects approach. Each participant completed a standardized CMJ protocol, and performance outcomes were analyzed using three predictive equations for power estimation. By this kind of design, will allow us for direct comparisons of methods while controlling for inter-individual variability.

Participants

Five healthy male students (age: 20.20 ± 0.20 years; height: 178.60 ± 4.72 cm; body mass: 73.00 ± 8.12 kg) volunteered to participate in this preliminary study. Subjects were physically active, accustomed to plyometric exercise, and free from musculoskeletal injuries of pain in the six months prior to testing. Inclusion criteria required participants to be engaged in regular sports practice, with previous experience in jump-based tasks. Exclusion criteria included any lower-limb injury, neuromuscular disorder, or current pain that could compromise safe performance. All participants were informed about the procedures and provided written consent. The research protocol was reviewed, registered, and approved by the institutional ethics committee (Registration number:210/16.04.2025). The study was con- ducted in accordance with the clarify guidelines and the ethical standards of the Declaration of Helsinki.

Instruments

For the anthropometry, the body height was measured to the nearest 0.1 cm using a wall mounted stadiometer (SECA, Germany). Body mass was recorded with an Omron digital scale (Omron Healthcare, Japan) to the nearest 0.1 kg. Although, for the jumping performance, the vertical height was assessed with the MicroGate OptoJump Next system (Microgate, n.d.).

Procedure

All tests were conducted on the same day under standardized conditions. Participants completed a general warm-up consisting of 5-7 minutes of light running and dynamic stretching, followed by mobility drills (leg swings, walking lunges, hip and ankle rotations) to increase muscle temperature and joint range of motion.

After general warm-up, a specific protocol was applied. The protocol is composed from 1-2 sets of repeated vertical jumps 15-s jump test) performed bilaterally with arm swing. Each set was separated by 1 minutes and 45 seconds of passive rest. This activation phase aimed to enhance neuromuscular readiness before maximal testing (Geantă & de Hillerin, 2025).

Subsequently, participants realized three maximal countermovement jumps (CMJs) with 60 second of rest between trials (Markovic et al., 2004). Each CMJ (see Figure 1) began from an upright standing position with free arm swing. Participants were instructed to descend rapidly to approximately 90° of the hips, knees and ankles. The highest jump recorded by the OptoJump Next system was used for the analysis.

Fig. 1. Schematic representation of the CMJ test

Data processing

The maximum jump height (cm) obtained from the three CMJ trials was used for subsequent analysis. Based on this value, together with each participant's body mass and height, average power outputs were computed using the following predictive equations:

Lewis (Fox & Mathews, 1974) – Average Power

$$P_{avg}(W) = \sqrt{4.9 \text{ x mass (kg)x} \sqrt{\text{VJ (m)x } 9.81}} \quad (1)$$

Harman et al. (1991) – Average Power

$$P_{avg}(W) = 21.2\ x \text{ VJ (cm)} + 23.0 \text{ x mass (kg)} - 1393 \quad (2)$$

Johnson & Bahamonde (1996) – Average Power

$$P_{avg}(W) = 41.4 \text{ x VJ (cm)} + 31.2 \text{ x mass (kg)} - 13.9 \text{ x height (cm)} + 431 \quad (3)$$

Where: P_{avg} = average power (W/kg); mass = body mass of the subject in kilograms (kg), height = body height in centimeters (cm); VJ = vertical jump height in meters (m) or centimeters (cm); 9.81 = gravitational acceleration in m/s^2.

All calculations were performed in Microsoft Excel 365, applying each predictive formula individually to all participants.

Statistical Analyze

Descriptive statistics (mean ± standard deviation) were calculated for all variables. Normality of distribution was assessed using the Shapiro–Wilk test. As the data were not normally distributed ($p < 0.05$), the Friedman non-parametric test was applied to compare the three predictive models of relative power (Lewis, Harman, and Johnson & Bahamonde). In addition to significance testing, effect size was quantified using Kendall's W, which represents the degree of concordance among repeated measures (Field, 2005). The statistic was calculated as χ^2 / [N × (k - 1)], where χ^2 is the Friedman test statistic, N is the number of participants, and k is the number of conditions compared. Kendall's W ranges from 0 (no agreement) to 1 (perfect agreement). According to Cohen's thresholds (Cohen, 2013), W ≥ 0.1 indicates a small effect, ≥ 0.3 a medium effect, and ≥ 0.5 a large effect. Statistical significance was set at $p < 0.05$. All analyses were conducted with IBM SPSS Statistics v.23 software (IBM Corp.).

RESULTS

The descriptive statistics for participants were as follows: age 20.20 ± 0.20 years, body mass 73.00 ± 8.12 kg, height 178.60 ± 4.72 cm, and CMJ performance 50.20 ± 6.07 cm (see Table 1).

Table 1. Descriptive statistics of the sample (M±SD)

Variable	**N**	**Mean**	**SD**
Age (years)	5	20.2	0.20
Weight (kg)	5	73	8.12
Height (cm)	5	178.6	4.72
CMJ (cm)	5	50.2	6.07

Note. Values are presented as mean ± standard deviation. CMJ = countermovement jump.

Regarding the predictive equations, average power outputs were 15.36 ± 0.99 W/kg for Lewis, 18.36 ± 2.23 W/kg for Harman, and 27.45 ± 4.41 W/kg for Johnson & Bahamonde.

Table 2. Descriptive statistics of predictive equations

Average power equation	**N**	**Mean**	**SD**	**Min**	**Max**
Lewis (W/kg)	5	15.36	0.99	13.6	16.1
Harman (W/kg)	5	18.36	2.23	14.4	19.7
Johnson & Bahamonde (W/kg)	5	27.45	4.41	19.68	30.21

Note. Power output was calculated according to three predictive models: Lewis (Fox & Mathews, 1974), Harman et al. (1991), and Johnson & Bahamonde (1996). Values are expressed as mean ± standard deviation.

The Friedman test (see Table 3) revealed statistically significant differences between the three formulas (χ^2 (2) = 10.000, p = 0.007, Kendall's W = 0.67, large effect). The mean ranks indicated a consistent progression, with Lewis producing the lowest values (mean rank = 1.00), Harman intermediate (mean rank = 2.00), and Johnson & Bahamonde the highest (mean rank = 3.00).

Table 3. Friedman test results

Test	χ^2	df	p	Kendall's W	Effect sig.
Friedman	10	2	0.007	0.67	Large

Note. The Friedman test was applied to assess differences between formulas. Kendall's W was used as an effect size index (W = 0.67, large effect according to Cohen's thresholds).

DISCUSSION

This study aimed to analyze three predictive equations commonly used to estimate lower-limb power from vertical jump performance and revealed statistically significant discrepancies between models. The Johnson and Bahamonde equations (1996) consistently produced higher values than the Harman et al. (1991) and Lewis models (Fox & Mathews, 1974), suggesting a systematic bias rather and random variation. The magnitude of the differences ($\chi^2(2) = 10.000$, $p = 0.007$, $W = 0.67$) indicates that the predictive methods do not yield interchangeable outcomes. This inconsistency challenges the assumptions that power estimates derived from jump height are theoretically and practically comparable across models (Canavan & Vescovi, 2004; Duncan et al., 2008; Wright et al., 2012; Kons et al., 2018).

A key finding of this study concerns the lack of dimensional homogeneity in the analyzed equations. Mechanically, power represents the rate of doing work overtime (W= J/s), as emphasized by Knudson (2009) and Nestle (2022). However, the evaluated predictive formulas combine variables such as body mass, jump height, and body height without including a temporal component. Although the computed outputs are expressed in watts (W), the underlying equations are dimensionally inconsistent. This inconsistency undermines their biomechanical validity and limits their interpretability as measures of actual mechanical power output. The results therefore highlight a fundamental methodological issue within many field-based assessments protocols that rely on empirically derived yet theoretically inconsistent models (Knudson, 2009; Eythorsdottir et al., 2024).

The use of the OptoJump Next system ensured high accuracy in measuring jump height, which strengthens confidence that the observed differences are due to the equations themselves rather than measurement errors (Glathorn et al., 2011; Yingling et al., 2018; Buscemi et al., 2019). Notably, similar methodological inconsistencies have also been identified in other jump-bases assessments. Geantă & de Hillerin (2025) reported substantial differences between predictive models of average power (Bosco, MG and MGM-15) in a 15-second repeated vertical jump test. The previous study indicated that the problem extends beyond single-jump protocol. This reinforces the conclusion that discrepancies originate from the mathematical structure of the predictive models (Xu et al., 2023; Eythorsdottir et al., 2024).

In applied contexts, such variability poses a problem for coaches, practitioners, and researchers, as athletes could be differently classified depending on the equation employed (Ache-Dias et al., 2016; Lara-Sánchez et al., 2011). Consequently, comparisons between studies, or even between athletes assessed with distinct formulas, may be misleading. The current findings thus stress the importance of methodological standardization in performance diagnostics and of avoiding overreliance on power estimators (Duncan et al., 2013; Pupo et al., 2020).

Despite its contribution, this investigation has limitations. The sample was small and homogeneous, reflecting the preliminary nature of the study. Only three equations were evaluated, and no direct comparisons with force-time data, the biomechanical gold standard was conducted (Alba-Jiménez et al., 2022; Xu et al., 2023; Cameron et al., 2025). Therefore, these findings cannot yet be generalized to broader population, or to other predictive models. Future research should expand the sample size, include additional equations, and integrate simultaneous force platform measurements to verify the magnitude of error across models. Approaches like this would provide stronger empirical and theoretical foundations for estimating lower-limb power from field tests.

CONCLUSIONS

The results of this preliminary investigation demonstrated that commonly used predictive equations for estimating lower-limb power form vertical jumps are not consistent. The Johnson and Bahamonde model produced the highest values, whereas the Lewis models yielded the lowest, with the Harman equations occupying an intermediate position. These systematic differences stem from dimensional inconsistencies within the equations, which combine variables with incompatible measurements units and omit the time component essential to the mechanical definition of power. Consequently, these predictive models do not represent true mechanical power output, but rather empirically derived performance variables.

The findings confirm that current field-based predictive formulas should be interpreted with caution and not used interchangeably. The study fulfills its objective of identifying theoretical and computational discrepancies among widely applied models and highlights the need to reconsider their validity in both research and practice.

Future work should develop consistent predictive methods that include time-dependent factors to match biomechanical principles. Building these models would improve the reliability and scientific accuracy of lower-limb power assessment. This would also help with more consistent evaluation and monitoring of athletic performance.

AUTHOR CONTRIBUTIONS

Vlad Adrian Geantă and Pierre Joseph De Hillerin contributed to the design and implementation of the research, as well as to the analysis of the results and the writing of the manuscript. Both authors have read and approved the final version of the article.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

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THE EXAMINATION OF THE EFFECTS OF BAREFOOT TRAINING ON RUNNING BIOMECHANICS, SPRINT PERFORMANCE, AND AGILITY DEVELOPMENT IN CHILDREN AGED 8 TO 11

Zsanett GERE[1*], Péter SZABÓ[2]

ABSTRACT. *Introduction*: the human foot has been described as a masterpiece of engineering and art, yet modern footwear has often limited its natural function and reduced sensory feedback. this has led to inefficient movement patterns in children and adults. *Objective*: the purpose of this study was to examine the effects of a ten-week barefoot training program on agility, sprint performance, and running biomechanics in children aged eight to eleven years. *Material and methods*: the program included three weekly sessions lasting seventy minutes each. sixteen children began the program, and nine completed it. assessments before and after the intervention included a change-of-direction speed test, a twenty-meter sprint, and biomechanical measurements of stance phase and ground reaction force using a motion analysis device. *Results*: the barefoot training program improved agility and sprint performance in the participants. significant reductions in stance phase duration were observed in the right leg, indicating shorter ground contact time and improved running efficiency. no meaningful changes were observed in the left leg or in the average ground reaction force for either leg. *Discussion*: the improvements in performance may be linked to enhanced foot strength and neuromuscular coordination. however, the small sample size and short intervention period limited the generalization of the findings. *Conclusions*: barefoot training appeared to improve agility, sprint speed, and running mechanics in children. it may strengthen the foot and support the inclusion of barefoot exercises in youth physical development programs.

Keywords: Barefoot training; running biomechanics; agility; sprint performance; children

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INTRODUCTION

In recent years, barefoot running has increased in popularity. Until the 1970s, most individuals, including athletes, ran barefoot or in minimal footwear. The introduction of the modern running shoe—with cushioned heels, arch support, and reinforced soles—marked a significant shift in running practices (Lieberman, 2012).

One reason for the renewed interest in barefoot running is that, despite technological advancements in running shoes, the incidence of running-related injuries has not decreased (Jenkins & Cauthon, 2011). Research indicates that the rate of such injuries is notably lower among barefoot runners (Robbins & Hanna, 1987). According to Lieberman (2012), a professor of biological anthropology at Harvard University, one cause of foot and knee injuries may be that modern running shoes weaken the muscles of the feet, leading to overpronation and related joint problems. The stiff soles and arch supports typical of conventional running shoes may impede the natural adaptation of muscles and bones (Lieberman, 2012). Moreover, individuals who wear expensive running shoes advertised as providing additional protective features (e.g., increased cushioning or "pronation correction") are significantly more likely to experience injuries than those who wear inexpensive shoes -less than 40 US dollar (Marti, Vater, Minder, & Abelin, 1988). Barefoot training is often promoted on the assumption that it strengthens the musculoskeletal system and consequently enhances athletic performance (de Villiers & Venter, 2014). For example, an eight-week study involving netball players found that participants who trained barefoot demonstrated significantly greater foot stability, agility, and sprint performance over 10 and 20 meters compared to those who trained wearing shoes. Lieberman (2012) emphasized that "how someone runs is probably more important than what they wear on their feet, but what they wear on their feet can affect their running" (p. 64). In other words, footwear can be a determining factor in both running success and injury risk. The influence of running shoes on landing patterns will be discussed in the following section.

1. Types of Foot Strike Patterns

The literature typically identifies three types of foot strike patterns in running:

- Rearfoot strike (RFS): the heel contacts the ground before the forefoot, commonly referred to as "heel-toe running."
- Forefoot strike (FFS): the forefoot contacts the ground before the heel ("toe-heel-toe running").
- Midfoot strike (MFS): the heel and forefoot contact the ground simultaneously, typically beginning with the outer edge of the sole. The heel remains on the ground only briefly before lifting again, functioning like a spring.

a.) MFS b.) FFS c.) RFS

Fig.1. 3 types of landing. Snapshot of a Barefoot training participant

2. The Ideal Landing Technique

It is often suggested that there are as many running techniques as there are runners. However, an important question arises: *Is there an ideal landing technique during running?* Brewer et al. (2017) found that when runners land on their heels, the foot typically strikes the ground ahead of the body's center of gravity. This movement disrupts forward momentum and requires greater energy expenditure to maintain speed. In contrast, when landing on the ball of the foot, the foot strikes the ground more vertically, minimizing braking forces and reducing the loss of momentum.

Approximately 75% of shod runners (i.e., runners wearing shoes) use a rearfoot strike (RFS) pattern, whereas barefoot runners more frequently adopt a midfoot strike (MFS) or forefoot strike (FFS) pattern. These strike types are associated with shorter stride lengths and lower stress on the ankle and Achilles tendon (Lieberman, 2012). Moreover, the more experience runners have running barefoot, the more likely they are to employ an FFS pattern (Lieberman et al., 2015).

3. Impact Peaks and Ground Reaction Forces

Lieberman et al. (2010) compared habitual barefoot runners with habitual shod runners and examined their ground contact techniques. The researchers found that the vertical impact peak force was approximately three times lower among habitual barefoot runners using an FFS pattern than among habitual shod runners using an RFS pattern, whether barefoot or wearing shoes. These findings suggest that forefoot striking may attenuate impact forces and potentially reduce injury risk.

4. Biomechanics of Galloping

Galloping is typically performed using a forefoot strike pattern. Sprinters generally possess a stiffer Achilles tendon than distance runners, which contributes to more efficient energy transfer during propulsion. Mizushima et al. (2021)

investigated the long-term effects of a school-based barefoot program involving children aged 10–12 years over a four-year period. Their findings indicated that barefoot participants exhibited shorter ground contact times, longer flight phases, and higher running speeds, regardless of footwear condition. In contrast, the control group, which wore shoes, showed no significant performance improvements associated with footwear use.

PURPOSE

The purpose of this research is to obtain empirical evidence regarding the performance benefits of barefoot training. Specifically, the study aims to examine the effects of regular barefoot training on agility and 20-meter galloping speed, comparing post-training outcomes to pre-training assessments. In addition, the research seeks to determine whether barefoot training produces measurable changes in running biomechanics during the stance phase.

More precisely, the study investigates how barefoot running influences the average horizontal ground reaction force (Fx Average) in the sagittal plane. The objectives of the 10-week training program are to improve movement speed combined with directional changes, enhance 20-meter galloping performance, and promote a more natural landing pattern during running. Furthermore, the program aims to increase overall performance, strengthen the leg and foot musculature, and reduce the risk of running-related injuries.

MATERIALS AND METHODS

Participants

Selection of Subjects

Between November and December 2023, researchers introduced the program to children in six primary schools, distributing informational leaflets to students in grades two through four. Written parental consent was obtained for all participants, in accordance with ethical research guidelines. The children contributed to the study by completing both pre- and post-training assessments and by participating in the full training intervention.

Description of Participants

The study sample was heterogeneous and selected using convenience sampling. Of the 16 initial participants, 9 completed the program, resulting in a dropout rate of approximately 50%. Eight participants were included in the biomechanical analysis of running, while nine completed the 20-meter gallop and 505-agility tests. The average age of participants was 10 years. The final sample included seven boys and two girls.

Procedure

The same assessments were administered during both the pre-test and post-test phases. These included the 505-agility test and the 20-meter gallop. In addition, running biomechanics were analyzed using a G-force measuring platform. The biomechanical variables measured were:

Ground contact time (stance time) – the duration of the foot's contact with the ground, and Horizontal ground reaction force (Fx) – the force exerted by the body against the ground in the front-to-back (sagittal) direction. Measurements were taken on January 9 and January 11, 2024 (pre-test), and again on March 26 and March 28, 2024 (post-test). The first testing session focused on assessing parameters related to running technique, while the second session included the galloping and 505-agility tests.

Tools and Methods Used in the Pre- and Post-Tests

505-Agility Test

Unit of Measurement: Seconds (s), recorded to two decimal places

Objective: To assess movement speed in combination with directional change

Description and Procedure: Participants began each trial from a standing start. Timing commenced with the initiation of movement. Each participant performed two trials per leg—one involving a turn to the left and the other to the right. The fastest time recorded across all trials was considered the final result.

20-Meter Gallop

Unit of Measurement: Seconds (s), recorded to two decimal places

Objective: To measure the ability to complete a 20-meter distance in the shortest possible time

Description and Procedure: Each participant started from a standing position with their preferred foot placed behind the starting line. Two attempts were performed, and the fastest recorded time was retained for analysis.

Measurement of Stance Phase Duration During Running Using a G-Force Measuring Platform

Unit of Measurement: Seconds (s), recorded to two decimal places

Objective: To measure the duration of the stance phase during running

Description and Procedure: Participants began from a standing start position, placed on a box or platform aligned with the G-Force measuring device. In response to an auditory signal, participants initiated running, ensuring that their trailing foot made contact with the force platform during the stance phase. Each participant completed three trials per leg, and the mean value of these three attempts was used for analysis.

Measurement of Horizontal Ground Reaction Force (Fx Average) Using a G-Force Measuring Platform

Unit of Measurement: Newtons (N)

Objective: To quantify the average horizontal ground reaction force (Fx Average) exerted by the body on the ground in the sagittal plane

Description and Procedure: This measurement followed the same protocol as the stance phase assessment. Participants performed the trials under identical conditions, and the average horizontal force generated during ground contact was recorded for analysis.

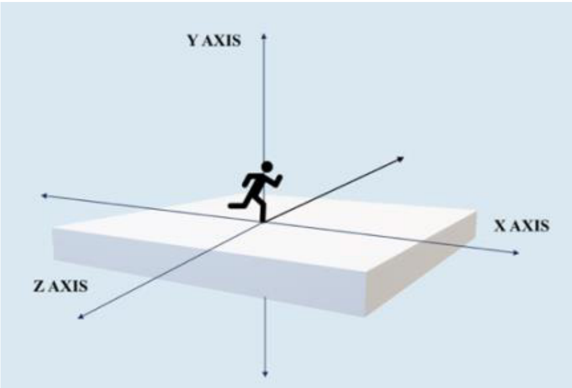

Fig. 2. Direction of the axes with respect to the center of gravity of the body.

Methods Used in the Research

Research Design

This study employed an experimental research design. Both primary and secondary data sources were utilized to collect information and statistical data. Primary data consisted of the children's individual measurements, training program details, and resulting performance outcomes. Secondary data were derived from theoretical knowledge and empirical studies in the existing literature, which informed the planning and structure of the training program. Information related to the design of the training program, test protocols, and exercise selection was gathered through a literature review of relevant academic and professional sources.

Materials

Applied Training Plan

The training plan was developed in accordance with the participants' age, motivation, and physical fitness, with intensity levels increasing progressively throughout the intervention. During the sessions, participants wore five-toed socks ("foot gloves") designed to closely replicate the mechanics and energetics of barefoot running. Training sessions were conducted three times per week, each lasting 70 minutes, between January 15, 2024, and March 24, 2024.

The first sessions took place on the indoor athletics track at the Iuliu Hațieganu University Sports Park, followed by sessions at the Cluj Arena indoor track. Each session was structured into three distinct components:

1. Warm-up phase: Activities designed to activate the leg and foot muscles.
2. Main phase: Running, jumping, strength, and agility exercises.
3. Cool-down phase: A progressively longer jog, concluding with the final half-lap at a submaximal pace.

The specific warm-up component aimed to prepare the lower limbs for dynamic activity and included the following exercises: running drills, preparatory and activation movements, foot massage using a tennis ball, heel and toe lifts, leg swings, running in place, and various gait patterns (e.g., bear walk).

Data Analysis

A combination of descriptive and inferential statistical methods was used to analyze the collected data. The test results were processed using percentages, statistical indicators, and the software programs SPSS and JASP. Additionally, Microsoft Word and Microsoft Excel were used for data organization and visualization. Results are presented in the form of tables and figures to enhance interpretability. To verify the assumptions for the paired-samples t-test, the Shapiro–Wilk test was performed to assess data normality. The results confirmed that the assumption of normality was met, indicating that the use of the paired-samples t-test was appropriate for the analyses.
Statistical significance was set at $p \leq .05$ for all analyses.

RESULTS

505-agility test

The processed data are expressed in seconds (s) to two decimal places, representing the time required for participants to complete the designed distance while performing a 180° change of direction from a standing start with each leg.

Table 1. Results of the paired-samples t-test comparing pre- and post-training performance for the left and right legs.

Paired Samples T-Test

Measure 1		Measure 2	t	df	p	Mean Difference	SE Difference
505_pretest_Left	-	505_post_Left	6.675	8	< .001	0.369	0.055
505_pre_Right	-	505_post_Right	2.532	8	.035	0.302	0.119

Note. Student's t-test. p <= .05

A paired-samples t-test was conducted to compare the pre- and post-training performance of the left leg in the 505-agility test. The analysis revealed a significant improvement from the pre-training measurement (M = 3.33, SD = 0.38) to the post-training measurement (M = 2.96, SD = 0.27), t(8) = 6.67, p < .001. These findings suggest that barefoot training positively influenced agility, specifically enhancing movement speed combined with rapid directional changes.

Table 1. also presents the pre- and post-training results for the right leg. A paired-samples t-test was conducted to compare pre- and post-training 505-agility performance for the right leg. The analysis revealed a significant improvement from the pre-training measurement (M = 3.27, SD = 0.46) to the post-training measurement (M = 2.97, SD = 0.17), t(8) = 2.53, p = .035.

For the left leg, all participants showed a decrease in time for movement speed combined with directional change. For the right leg, all participants except two demonstrated a reduction in time. These findings indicate that barefoot training positively affects agility, specifically by enhancing movement speed in combination with rapid changes in direction.

20-Meter Distance Run

Table 2. Results of the paired-samples t-test comparing pre- and post-training performance in the 20 meter gallop.

Paired Samples T-Test

Measure 1		Measure 2	t	df	p
20_m_pretest	-	20_m_post test	2.583	8	0.32

Note. Student's t-test. p <= .05

Table 2 presents the results of the paired-samples t-test comparing pre- and post-training performance in the 20-meter gallop. Performance was measured as the time required to complete the designated distance from a standing start, expressed in seconds. All participants except two (participants 6 and 7) demonstrated a decrease in completion time.

A paired-samples t-test was conducted to compare pre- and post-training performance. The analysis revealed a significant improvement from the pre-training measurement (M = 4.02, SD = 0.42) to the post-training measurement (M = 3.77, SD = 0.24), t(8) = 2.58, p = .032.

These findings indicate that barefoot training positively affects galloping performance, specifically by improving forward speed.

Support phase results

Table 3. Results of the paired-samples t-test comparing pre- and post-training performance for the left and right legs in stance phase duration.

Paired Samples T-Test

Measure 1		Measure 2	t	df	p
Stance_ph_pre_L	-	Stance_ph_post_L	0.800	7	.450
Stance_ph_pre_R	-	Stance_ph_post_R	2.255	7	.059

Note. Student's t-test. p <= .05

Table 3 presents the results of the paired-samples t-test comparing pre- and post-training stance phase duration for the left and right legs. Stance phase duration was measured as the time (s) each participant's foot remained in contact with the force platform during running from a standing start.

A paired-samples t-test was conducted to compare pre- and post-training measurements for the left leg. No significant difference was found between the pre-training (M = 0.29, SD = 0.03) and post-training (M = 0.28, SD = 0.06) measurements, t(7) = 0.80, p = .450. Although the difference was not statistically significant, a partial improvement in stance phase duration was observed among the participants. All participants, except two (participants 4 and 8), demonstrated a decrease in stance time, and one participant's time remained unchanged.

A paired-samples t-test was conducted to compare pre- and post-training stance phase duration for the right leg. The analysis revealed a significant reduction from the pre-training measurement (M = 0.29, SD = 0.038) to the post-training measurement (M = 0.26, SD = 0.036), t(7) = 2.25, p = .05. These results suggest that barefoot training influenced the stance phase, resulting in a shorter ground contact time.

A shorter stance phase generally corresponds to an increased flight phase and higher running speed (Kennedy, 2018). The stance phase can be divided into three major components: the amortization phase, the verticality phase, and the momentum phase (Szabó & Vasile, 2010). During the momentum phase, which serves as the primary propulsive phase of the running stride, rapid and forceful extension of the supporting leg is required. As running speed increases and the stance phase shortens, the momentum phase must occur more rapidly and powerfully, resulting in a stronger, more explosive push-off from the supporting leg.

Previous research suggests that shorter ground contact times are often associated with forefoot strike (FFS) or mid-midfoot strike (MMS) patterns, as heel contact typically requires more time (Hasegawa, Yamauchi, & Kraemer, 2007). It is therefore plausible that the reduced stance phase observed in the current study reflects an adoption of FFS or MMS running patterns. However, further investigation using more advanced biomechanical measurement tools is necessary to confirm this hypothesis.

Measurement of the force exerted by the body on the ground on the x-axis (front-back direction) (Fx Average)

Table 4. Results of the paired-samples t-test comparing pre- and post-training performance for the left and right legs in average ground reaction force along the x-axis (front–back direction; Fx Average).

Paired Samples T-Test

Measure 1		Measure 2	t	df	p
Fx_av_pre_L	-	Fx_av_post_L	0.679	7	.519
Fx_av_pre_R	-	Fx_av_post_R	1.509	7	.175

Note. Student's t-test. $p <= .05$

Pre- and post-training anterior–posterior ground reaction force measurements were recorded in Newtons (N), with negative values indicating force applied in the anterior–posterior direction. These values represent the horizontal force exerted by participants on the ground from a standing start in the sagittal plane.

A paired-samples t-test was conducted to compare pre- and post-training measurements. No significant difference was observed between the pre-training ($M = –59.44$, $SD = 20.42$) and post-training ($M = –64.73$, $SD = 33.64$) measurements, $t(7) = 0.68$, $p = .519$. Despite the lack of statistical significance, a partial improvement is evident, as many participants exhibited reduced force exertion. These findings suggest that during ground contact, the reduced horizontal force may indicate decreased impact on the body, resulting in a lower load on the musculoskeletal system. All participants except three (participants 5, 7, and 8) demonstrated a decrease in force magnitude for the left leg.

A paired-samples t-test was conducted to compare pre- and post-training measurements. No significant difference was found between the pre-training ($M = -52.92$, $SD = 13.39$) and post-training ($M = -62.42$, $SD = 22.35$) measurements, $t(7) = 1.51$, $p = .175$. Despite the absence of statistical significance, a partial improvement was observed, as the horizontal force decreased for many participants. A reduction in force magnitude was observed for all participants except two (participants 3 and 5) for the right leg.

This reduction suggests that during ground contact, participants experienced lower impact forces, resulting in a reduced load on the musculoskeletal system.

DISCUSSION

In accordance with the research objectives, this study analyzed the changes resulting from a ten-week barefoot training program, as reflected in differences between pre- and post-training measurements. The program led to improvements in foot mechanics and running performance in children aged 8–11 years. It produced significant gains in 505-agility ($p = .035$) and 20-m gallop speed ($p = .032$), together with a shortened right-leg stance phase ($p = .05$). Similar performance benefits have been reported in other youth and adult cohorts. De Villiers & Venter (2014) observed that eight weeks of barefoot training improved ankle stability and agility in netball players, mirroring the present study's agility gains despite a different sport context. Mizushima et al. (2021) examined a four-year school-based barefoot program and documented reduced ground-contact times, longer flight phases, and faster sprint speeds across ages 10-12, aligning with our finding that a shorter stance phase translates to higher running speed. Early injury-prevention work by Robbins & Hanna (1987) reported lower running-related injury incidence among barefoot runners, supporting the notion that the biomechanical adaptations seen here (e.g., reduced horizontal ground-reaction force, though not statistically significant) may confer protective effects.

Finally, Lieberman (2012) highlighted that habitual barefoot runners tend to adopt fore- or mid-foot strike patterns, which lower impact peaks and improve efficiency; our observed right-leg stance reduction likely reflects a shift toward such strike patterns, as suggested in the discussion. Consequently, despite variations in sample size, duration, and sport-specific tasks, the studies consistently demonstrate that barefoot training enhances neuromuscular efficiency, shortens ground-contact time, and yields measurable improvements in speed and agility.

CONCLUSIONS

The ten-week barefoot training program produced measurable improvements in running performance, stance phase stability, and the strength of the foot and ankle musculature in children aged 8–11 years. A statistically significant reduction in stance phase duration was observed in the right leg, indicating a potential improvement in running efficiency; however, no significant changes were found in the left leg or in the average horizontal ground reaction force.

Due to the small sample size, participant dropout, and the short duration of the intervention, the findings cannot be generalized to the wider population. The results should therefore be interpreted as preliminary and exploratory. Nevertheless, the observed trends are consistent with previous research reporting beneficial adaptations in neuromuscular coordination and foot function following barefoot or minimal-footwear training.

Further studies with larger samples, longer intervention periods, and more comprehensive biomechanical analyses are required to confirm these findings and to better understand the long-term effects of barefoot training on running mechanics and performance in children.

AUTHOR CONTRIBUTIONS

Zsanett Gere and Péter Szabó contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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THE INFLUENCE OF TAPING TECHNIQUES APPLIED TO THE PHALANGES OF THE DOMINANT HAND ON THROWING ACCURACY AND ACCELERATION IN HANDBALL

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ABSTRACT. *Introduction:* the study addressed the potential influence of finger taping on handball performance, considering that both power and accuracy are essential for success and that athletes often rely on preventive strategies when facing finger or hand injuries.*Objective:* the objective was to examine whether different finger taping configurations affected acceleration, applied force, and throwing accuracy during standardized handball throws. *Material and methods*: ten participants between 19 and 23 years of age were recruited. each performed forty throws under four distinct *Conditions:* without taping, with the little finger taped to the ring finger, the ring finger taped to the middle finger, and the middle finger taped to the index finger. all throws were executed from a standing position at nine meters, following an auditory signal. a precision net was used to restrict the throws to the corners of the goal. *Results:* the analysis showed only minor differences across the four conditions. these differences appeared to be related to the limited sample size, the reduced number of repetitions, and the natural variation in skill level among the participants. *Discussion:* although the variations were small, the findings aligned partially with previous research suggesting that external support strategies may subtly influence throwing mechanics. the results indicated that the potential effects of taping may not be fully captured within

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small-scale trials. *Conclusions*: finger taping did not substantially alter throwing performance in this study. however, further research with larger samples and extended protocols is recommended to clarify its role in competitive handball.

Keywords: taping, acceleration, force, accuracy, handball, throw

INTRODUCTION

Sports and physical education are key elements to a healthy lifestyle. Sports are structured physical activities carried out by virtue of some rules and require focused training with the intention to achieve outcomes or performance. These activities define an individual's lifestyle, enhance health condition, and enhance character formation (Santa-Moldovan et al., 2024). It is known well that sport and physical health connection is one of the prime topics of medicine, physiology, sport science, and psychology. This connection is further extended to sociology research fields as well, particularly public health surveys, interviews, and questionnaires being carried out as prime research methods. These studies continuously indicated notable favorable connections between participation in sports and improvement in physical and mental health. For example, in the early 1990s, extensive surveys were conducted on nationally representative populations of between 3,500 and 6,500 participants, some of which were developed and implemented by the Public Census and Investigation Office (Șerban & Baciu, 2017).

The human body is continuously exposed to external forces and impacts to which the muscles respond through contraction. These contractions can be negative (eccentric) or positive (concentric). During eccentric contractions, the muscles undergo a lengthening phase characterized by elasticity or stretching (negative action), whereas during concentric contractions, the muscles experience a shortening phase with elastic force generation (positive action) (Pop et al., 2008).

Strength training is essential as it serves a protective purpose: stronger muscles are able to absorb weight and tensile forces before failure occurs at the muscle or musculo-tendinous junctions. Any deficiency in muscle strength, asymmetry, or imbalance can lead to musculoskeletal injuries such as patellofemoral pain and lesions resulting from the weakening of the vastus medialis oblique fibers, as well as shoulder pain and dysfunction due to decreased strength of the stabilizing muscles (Pop & Chihaia, 2015).

Important factors in preventing injuries during training and competitions include proper recovery and rebuilding after effort, as well as adequate warm-up and stretching. Equally important is adherence to training planning and periodization to ensure injury prevention, considering the program established at both national and international levels, along with the objectives of the team (Pop & Chihaia, 2015).

When performed correctly, stretching exercises offer benefits that go beyond merely enhancing flexibility. They improve both physical and mental relaxation, lower the risk of injury to joints, muscles, and tendons, decrease post-exercise muscle tension and soreness, and enhance mobility by stimulating the production of synovial fluid in the joints as well as the components that make up connective tissue (Pop & Chihaia, 2015).

Handball is a complex sport that requires a high degree of coordination, speed and precision in the technical elements and procedures performed by the players. These abilities are strongly influenced by the proper functionality of the athlete's upper and lower limbs (Anderson et al., 2020). Taping procedures are prevention procedures of injuries or, in case of finger injuries (Bahr & Krosshaug, 2005). Used when it is not fully recovered yet, there are procedures to immobilize two side-by-side-fingers to permit further activity by the athlete (Laver et al., 2018). Sport and physical education are a determinant factor regarding the construction of an active and healthy lifestyle with implications not only towards motor development itself but towards socialization as well. Extracurricular sporting activities significantly contribute to extracurricular learning by providing learners with chances to train motor skills and to achieve useful skills towards life and towards society (Prodea, Joldeș, & Pop, 2020). Meanwhile, at high performance level, there is a priority to undertake individualization at training and to prevent injury employing enhanced monitoring techniques. The assessment of cardiorespiratory capacity, like VO_2max determination employing standard procedures, provides helpful information regarding effort-related body reaction and permits training loads to adapt to each athlete's profile (Tărăran, Tărăran, & Păunescu, 2023). The application of any such research protocols is relevant towards performance optimization itself but towards risk reduction regarding fatigue and injury and is indeed crucial towards achieving long-term excellence by elite athletes. Thus, physical education, extracurricular activities, and application of enhanced scientific evaluation tools are ancillary and add towards health and performance and support them reciprocally.

Modern sports conditioning and physical education are increasingly founded upon scientifically justified protocols that optimize performance while diminishing injury risk and promoting effective rehabilitation. Early physical education programs have been shown to improve gross motor proficiency—balance, coordinating and entire-body controlling young children substantially and this lays foundations both for sporting development and for diminishing risk to injuries further through life (Boros-Balint et al., 2022). In rehabilitation schemes, post-operative knee protocols involving appropriate positioning for exercises, graduated frequency and intensity are pivotal to allowing tissue repair while maintaining functional mobility (Racolta et al., 2009). Further, new preparatory procedures, whole-body vibration, stimulus-variance regimes and proprioceptive training—hold exciting hopes for accelerated recovery and maintaining strength amongst untrained or recovering populations (Racolta et al., 2009). As a group, these studies highlight education involving physical movement, early motor maturity and carefully constructed recoveratory protocols as key pillars to today's sport and movement sciences. This research starts from the premise that the application of taping techniques may influence, to a certain extent, the strength, accuracy and acceleration of a throw in handball. The dominant hand is the primary tool of execution and therefore it must function optimally and within normal parameters to maximize the force, acceleration and accuracy of a throw (Weber et al., 2014). Consequently, this study focuses on evaluating the impact of taping techniques applied to the phalanges of the dominant hand on these essential parameters for handball performance.

The importance of this topic is significant, as it can enhance athletic performance and prevent injuries. The results of this research may have practical applications in developing personalized strategies for athletes, adapted to their needs and biomechanical particularities.

MATERIAL AND METHODS

The main method used in conducting this study was the experimental method. This research method involves modifying or creating certain factors to determine a phenomenon, under conditions chosen by the researcher. An experiment implies isolation or, more precisely, the focus of attention on the specific subject or target group, followed by the application of a series of tests to observe how the group being tested reacts because of the tests performed.

Ten subjects participated in this experiment, 3 female and 7 males, aged between 19 and 23. According to the informal interview, 2 of the subjects play handball at a professional level, while 8 have an average of 10 years of handball experience. The subjects of this test signed a consent form for voluntary participation in the experiment. For this study, the 10 subjects were not divided into groups, but remained together in a single group of 10.

The objectives of this research are to obtain accurate data using sensors that transmit in real time the throwing force, acceleration and accuracy of the examined individual, to compare different sets performed under various conditions.

The experimental trial was carried out as follows: the subject stood with their back to the goal, on the 9-meter semicircle, holding the ball at chest level with both hands. At the first auditory signal given by the application, the subject had to prepare, as the next auditory signal they had to turn as quickly as possible and throw as accurately as possible at the goal, aiming for one of the four corners of the goal for the throw to be considered successful. The sensors were placed on the arm and on the wrist using specific elastic bands and the middle finger were taped together, and in the fourth set, the index finger and the middle finger were taped together or straps. Everyone completed 4 sets of tests, with 10 repetitions per set. In the first set, the fingers were not taped, in the second set, the little finger and the ring finger were taped together; in the third set, the ring finger.

The materials used were as follows:

- Taping band for binding two fingers. Adhesive tape for fixation made of white synthetic silk, with synthetic adhesive in strips. Water repellent when impregnated, highly permeable to air, easily removable without leaving residues. Dimensions: 2.5cm x 9.2m.
- Kipsta SG500 precision net: dimensions 3x2m and weight of 800g, main material: 100% polyester, strap: 100% polypropylene.
- Two smartphones, one for the Movella Dot kit application and one for the stopwatch-type application “On Your Marks”. Nokia G60 5G: Android 12 operating system, height 166mm, width 75.93mm, thickness 8.61mm, weight 190g, battery 4500mAh, 6GB RAM, 128GB internal storage, Snapdragon 5G processor. Samsung Galaxy A54: Android 13 operating system, height 158.2mm, width 76.7mm, thickness 8.2mm, weight 202g, battery 5000mAh, 8GB RAM, 128GB internal storage, Exynos 1380 octa-core processor.
- “On Your Marks” application, which simulates the start of a race by setting time intervals between “On Your Marks” and “Ready” as well as between “Ready” and the signal. This application calculates reaction time.
- Movella Dot accelerometer kit, containing 5 sensors, charging case with cables, sensor mounts, straps, and elastic bands of various sizes to which the sensors are attached. Included: one strap 5.08cm x 128cm, two straps 5.08cm x 55cm, two straps 5.08cm x 29cm, elastic band for forearm 15-20 cm, elastic band for lower limb 26-38 cm, elastic band for arm 22-34cm, elastic band for thigh 40-52cm. Materials: Lycra for elastic bands, fabrifoam and plastic for straps and fasteners. Sensor size: 36.3 x 30.35 x 10.8 mm, weight 11.2g, 70mAh battery, Bluetooth 5.0 compatible with both Android and iOS.

· Movella application, which allows us to control Movella DOT wearable sensors from the smartphone. Key features: scanning and connecting sensors, data measurement and recording, magnetic field mapping (MFM), and Over-the-Air (OTA) firmware upgrades.

Research Structure: The research process involved recruiting the subjects, gathering at the 'Gheorghe Roman' sports hall of the Faculty of Physical Education and Sport, signing the informed consent forms, explaining and demonstrating the testing procedure, performing throws without sensors, preparing the body for effort with selective activation of the locomotor system, and finally executing throws both without and with sensors attached.

Measurement Protocol: The measurement protocol consisted of choosing the appropriate strap or sleeve, attaching and starting the sensors, connecting them to the smartphone application, positioning the subject at 9 meters, initiating the recording in the Movella DOT application and the On Your Marks software, performing 10 throws across four series, then stopping both the software and sensors, and finally removing the sensors.

Taping Protocol: The taping protocol involved binding the little finger with the ring finger, the ring finger with the middle finger, and the middle finger with the index finger, each pair being wrapped at least five times so that the fingers moved as a single unit.

RESULTS

Table 1. Data distribution

	Statistic	df	p
Ar1_Sz1_AccAverage	.879	7	.223
Ar1_Sz1_AccMax	.836	7	.091
Ar1_Sz2_AccAverage	.948	7	.714
Ar1_Sz2_AccMax	.888	7	.267
Ar2_Sz1_AccAverage	.867	7	.175
Ar2_Sz1_AccMax	.842	7	.104
Ar2_Sz2_AccAverage	.940	7	.638
Ar2_Sz2_AccMax	.967	7	.873
Ar3_Sz1_AccAverage	.871	7	.188
Ar3_Sz1_AccMax	.798	7	.069
Ar3_Sz2_AccAverage	.833	7	.085
Ar3_Sz2_AccMax	.922	7	.485
Ar4_Sz1_AccAverage	.927	7	.528
Ar4_Sz1_AccMax	.923	7	.495
Ar4_Sz2_AccAverage	.874	7	.201

	Statistic	df	p
Ar4_Sz2_AccMax	.797	7	.068
ProcSet1	.919	7	.461
ProcSet2	.949	7	.720
ProcSet3	.859	7	.147
ProcSet4	.840	7	.099

Considering that the values obtained in the p-column are greater than 0.05, we can say that the data are properly distributed.

Table 2. ANOVA test results

Parameter	Variable	N	Average	Standard Deviation	Min	Max	df	Average Square	F	p
Sz1_AccAverage	Ar1	7	5.82	1.46	3.81	7.34	3	4.773	2.402	.093
	Ar2	7	5.97	1.30	4.49	7.53				
	Ar3	7	6.42	1.62	4.70	8.81				
	Ar4	7	7.64	1.19	5.50	8.96				
Sz1_AccMax	Ar1	7	7.74	2.74	4.85	11.01	3	6.794	1.302	.297
	Ar2	7	7.38	2.09	5.05	9.78				
	Ar3	7	8.77	2.61	5.36	11.15				
	Ar4	7	9.54	1.45	7.19	11.26				
Sz2_AccAverage	Ar1	7	6.39	1.75	3.86	8.72	3	1.128	.586	.630
	Ar2	7	5.94	1.27	4.30	7.66				
	Ar3	7	6.14	1.22	4.74	7.49				
	Ar4	7	5.45	1.22	3.86	7.89				
Sz2_AccMax	Ar1	7	7.90	2.52	4.63	11.36	3	1.398	.294	.829
	Ar2	7	7.67	2.08	5.03	11.00				
	Ar3	7	8.10	1.91	5.37	10.38				
	Ar4	7	7.07	2.15	5.23	11.37				
Proc	Ar1	7	27.14	22.88	.00	60.00	3	32.143	.107	.955
	Ar2	7	31.42	21.93	.00	60.00				
	Ar3	7	31.42	12.15	20.00	50.00				
	Ar4	7	28.57	6.90	20.00	40.00				

Considering that the p-values are greater than 0.05, we cannot say that there is a significant difference between the four types of throws. The only point of interest is Sz1_AccMedie, where p = 0.093, which is the value closest to 0.05, suggesting a trend toward signification.

Table 3. Bonferroni test results

Dependent Variable	(I) Throw	(J) Throw	Difference of average (I-J)	Standard error	p	95% Confidence Interval	
						Lower Bound	Upper Bound
Sz1_AccMedie	Ar1	Ar2	-0.147	0.754	1.000	-2.3138	2.0190
		Ar3	-0.601	0.754	1.000	-2.7678	1.5650
		Ar4	-1.820	0.754	.142	-3.9862	.3466
	Ar2	Ar3	-0.454	0.754	1.000	-2.6204	1.7124
		Ar4	-1.672	0.754	.217	-3.8388	.4940
	Ar3	Ar4	-1.218	0.754	.714	-3.3848	.9480
Sz1_AccMax	Ar1	Ar2	0.364	1.221	1.000	-3.1466	3.8746
		Ar3	-1.027	1.221	1.000	-4.5376	2.4836
		Ar4	-1.800	1.221	.920	-5.3110	1.7101
	Ar2	Ar3	-1.391	1.221	1.000	-4.9016	2.1195
		Ar4	-2.164	1.221	.534	-5.6751	1.3461
	Ar3	Ar4	-0.773	1.221	1.000	-4.2840	2.7371
Sz2_AccMedie	Ar1	Ar2	0.455	0.741	1.000	-1.6757	2.5864
		Ar3	0.259	0.741	1.000	-1.8718	2.3903
		Ar4	0.949	0.741	1.000	-1.1821	3.0801
	Ar2	Ar3	-0.196	0.741	1.000	-2.3271	1.9350
		Ar4	0.494	0.741	1.000	-1.6374	2.6247
	Ar3	Ar4	0.690	0.741	1.000	-1.4414	2.8208
Sz2_AccMax	Ar1	Ar2	0.229	1.166	1.000	-3.1228	3.5812
		Ar3	-0.203	1.166	1.000	-3.5547	3.1493
		Ar4	0.830	1.166	1.000	-2.5221	4.1818
	Ar2	Ar3	-0.432	1.166	1.000	-3.7839	2.9201
		Ar4	0.601	1.166	1.000	-2.7513	3.9526
	Ar3	Ar4	1.033	1.166	1.000	-2.3194	4.3845
Proc	Ar1	Ar2	-4.286	9.258	1.000	-30.9039	22.3325
		Ar3	-4.286	9.258	1.000	-30.9039	22.3325
		Ar4	-1.429	9.258	1.000	-28.0468	25.1896
	Ar2	Ar3	0.000	9.258	1.000	-26.6182	26.6182
		Ar4	2.857	9.258	1.000	-23.7611	29.4753
	Ar3	Ar4	2.857	9.258	1.000	-23.7611	29.4753

This test is used only if ANOVA indicates significance. In my case, no test was significant, all p-values were greater than 0.05, so Bonferroni interpretation has only exploratory value. However, we have an average difference of -1.820 with p=0.142, which indicates a difference of nearly two units, potentially of practical relevance, even if not statistically significant. All p-values from the ANOVA test were above 0,05, meaning that no statistically significant differences were identified between the types of throws regarding average or maximum acceleration. The Bonferroni test did not identify significant differences between throw pairs, although toward significance can be observed in Sz1_AccAverage between Ar1 and Ar4.

DISCUSSION

Following the ANOVA and Bonferroni tests, certain differences between the throwing conditions were observed, although these did not reach statistical significance. One possible explanation is related to the way average acceleration was calculated, namely across the entire execution phase of the throw. Previous biomechanical research has shown that temporal characteristics of throwing movements can substantially influence kinematic outputs, even when peak values remain unchanged (Weber et al., 2014). Variations in throw duration induced by finger taping may therefore alter average acceleration values without necessarily affecting maximal acceleration.

In addition, biomechanical constraints induced by finger taping may lead to subtle neuromuscular and kinetic chain adaptations. Binding two adjacent fingers can increase tension in the forearm musculature and alter finger–ball interaction, potentially affecting force transmission and release mechanics. Similar observations have been reported in studies examining external support and injury-prevention strategies, where mechanical constraints did not substantially impair performance but induced compensatory adjustments in movement patterns (Bahr & Krosshaug, 2005).

Another factor that may explain the variability in acceleration values is the use of an auditory stimulus to initiate the throw. Reaction-based motor tasks introduce additional cognitive and attentional demands, which can influence movement timing and coordination. Previous studies have demonstrated that externally triggered movements may result in small inconsistencies in execution, particularly in complex, whole-body actions such as throwing (Anderson et al., 2020).

The absence of statistically significant differences may also reflect the relatively high and homogeneous level of handball experience among participants. Experienced athletes are known to adapt rapidly to mechanical constraints and external perturbations, preserving task performance through motor redundancy and compensatory strategies (Laver et al., 2018).

Although the ANOVA test followed by the Bonferroni correction did not reveal statistically significant differences between the four types of throws, the observed differences in mean values—particularly between Ar1 and Ar4—suggest potentially meaningful quantitative trends. Similar findings have been reported in applied sport science research, where non-significant statistical outcomes still reflected practical effects limited by small sample sizes or high inter-individual variability (Weber et al., 2014).

Regarding Figure 1, although no statistically significant differences were found in Sz1_AccAverage, a progressive increase in mean acceleration was observed as taping shifted toward distal phalanges. This trend may indicate a modification of throwing biomechanics, potentially characterized by a more pronounced proximal-to-distal sequencing or "whip-like" effect, as grip stability decreases with distal finger restriction (Weber et al., 2014).

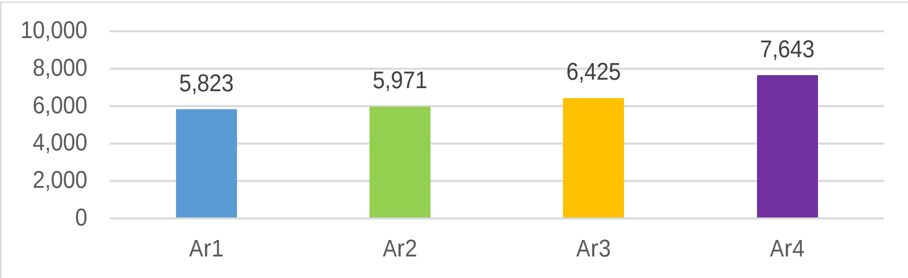

Fig. 1. The Sz1_AccAverage value for the four variables Ar1, Ar2, Ar3, and Ar4

Although there is no statistically significant difference between the mean acceleration values recorded by the first sensor for the four variables, a difference can still be observed. Interestingly, the trend of the average acceleration value for Sz1 increases as the taping shifts toward the distal phalanges. The lack of statistically significant differences may be due to the small sample size, as well as the fact that all subjects had medium/high-level handball experience, which may have led to an adaptation to this type of restriction of phalangeal mobility. The increase in mean acceleration for Sz1 may indicate a modification of the throwing biomechanics, caused by a more pronounced whipping effect as the grip on the ball decreases when the fingers are taped more distally.

CONCLUSIONS

The conclusions obtained from conducting an experiment must be consistent with the results observed after its completion. In this paper, starting from the proposed hypothesis—namely, "Whether the taping techniques used by handball players on the phalanges of the dominant hand influence the accuracy and acceleration of the throw in handball"— the following was deduced:

· There is a small difference that was identifiable through statistical tests.

· The results obtained were not statistically significant.

· This difference is insignificant due to the limitations encountered during the examination: small group size, limited number of throws, and the level of preparation.

· If this experiment were conducted at a higher level—with more participants, a greater number of throws, and varying levels of training, significant results would most certainly be found.

At the present, based on the tests that were conducted, and the statistical results obtained, it can be concluded that there are no significant differences regarding whether the taping techniques used by handball players on the phalanges of the dominant hand influence the accuracy and acceleration of the throw in handball.

AUTHOR CONTRIBUTIONS

Alexandru Andrei Gherman, Raul Octavian Achim, Adrian Pătrașcu, and Leon Gomboș contributed equally to the design and implementation of the research, to the data collection, analysis and interpretation of the results, and to the writing of the manuscript. All authors had equal rights and responsibilities in the preparation of this work. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest related to this research.

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PHYSIOTHERAPEUTIC INTERVENTION IN HUNTINGTON'S DISEASE – CASE STUDY

Maria-Ramona GRUIESCU[1], Ana-Maria VUTAN[1*], Corina Marina PANTEA[1]

ABSTRACT. *Introduction:* Huntington's disease is a hereditary neurodegenerative disorder characterized by motor, cognitive, and behavioral symptoms, with onset between 30 and 50 years of age. *Objectives:* The aim of this study was to evaluate the impact of physiotherapy on mobility, motor control, and balance, aiming to improve the quality of life of the patient in daily activities. *Material and Methods:* The study was conducted on a 47-year-old patient diagnosed with Huntington's disease at age 39. Over 10 weeks, with 3 weekly physiotherapy sessions, four assessment stages were performed using the following scales: Mini-Mental State Examination for cognition, Berg and Tinetti Scale for balance, Fahn-Marsden Scale for dystonia, and Activities of Daily Living for daily activities. *Discussions:* The results indicated significant improvements in balance and motor control, as well as a slight improvement in dystonic movements and independence in daily activities, especially in personal hygiene. *Conclusions*: The study concludes that physiotherapy interventions can slow the progression of symptoms and contribute significantly to improving the quality of life of patients with Huntington's disease, highlighting the importance of this therapy.

Keywords: Huntington's disease; physical therapy; involuntary movements; quality of life.

INTRODUCTION

Huntington's disease, first described by Waters in 1842 and detailed by George Huntington in 1872, is a neurodegenerative disorder with onset in middle age, characterized by involuntary movements, cognitive and behavioral disorders, and dementia. In 1993, the discovery of the HTT gene on chromosome

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4 revolutionized the understanding and treatment of the disease, becoming a model for medical research. The disease is caused by the expansion of the CAG trinucleotide in the HTT gene, which produces the mutant huntingtin protein, responsible for neuronal toxicity. It is an autosomal dominant condition, with a 50% probability of being transmitted to offspring (Bates, 2015; Roos, 2010).

Mutant huntingtin protein affects neuronal structure and function through abnormal aggregation, mitochondrial dysfunction, disruption of axonal transport, and alterations in gene expression. The secretion of neurotransmitters such as dopamine, glutamate, and GABA is imbalanced, leading to damage to the basal ganglia and cortex, which are involved in movement control and cognitive functions. The first molecular signs are detectable 15 years before the onset of clinical symptoms (Bates, 2015; Irfan, 2022).

Motor symptoms include chorea, bradykinesia, rigidity, and dystonia. Cognitive disorders are manifested by slowed thinking, memory impairment, and difficulty in planning. Psychiatrically, patients may present with depression, anxiety, apathy, and behavioral disorders, often preceding motor symptoms. The disease progresses progressively, leading to total dependence and severe disability in advanced stages (Caron et al, 1998; Roos, 2010).

Diagnosis is based on: medical and neurological history (analysis of reflexes, coordination and mental status), imaging (MRI/CT reveals striatal and cortical atrophy), and genetic testing (identifies CAG extensions in the HTT gene, considered the defining criterion) (Bates, 2015; National Institute of Neurogical Disorders and Stroke, 2025).

Direct genetic testing is the reference method, complemented by imaging investigations and analyses to exclude other conditions. The symptomatic triad (motor, cognitive and neuropsychiatric disorders) defines the disease, being supported by visual and olfactory abnormalities (National Institute of Neurogical Disorders and Stroke, 2025).

Huntington’s disease is a complex condition with multisystemic impact. Current research allows for early diagnosis and opens up therapeutic perspectives, especially in preclinical stages (Bates, 2015).

Huntington’s disease is progressive, with a median survival of 15–25 years after onset. Death is frequently due to pneumonia, cardiovascular complications, and conditions such as choking, fractures, and suicide. Choreic movements increase the risk of head trauma (Caron et al, 1998, Liou, 2010)

Although there is no cure, patients are treated with various therapeutic interventions, taking into account their symptoms. Thus, interventions can be made with: **physical therapy -** for maintains mobility, preventing contractures, and improving balance through adapted exercises in order to reduce the risk of falls, and correcting gait and posture (Fritz et all, 2017, Quinn, L., & Rao, A. 2002); **occupational therapy** – for promoting the independence through environmental adaptation and the use of assistive devices (Bilney et al, 2003; Simon-Vicente et al, 2023); **speech therapy** - addresses dysphagia and speech disorders through muscle exercises and nutritional guidance (Liou, 2010); p**sychotherapy** - focuses on managing depression, anxiety, apathy, and other cognitive and behavioral problems and cognitive behavioral therapy is effective in obsessive-compulsive disorders (Zanotti et al, 2020); **drug treatments** – motor and cognitive symptoms are managed with medications, but their choice must balance efficacy and the risks of adverse effects (Liou, 2010).

Patients affected by this rare degenerative disease often face considerable difficulties in obtaining adequate care and effective treatments. This condition presents a distinct challenge, as its diagnosis and management often require specialized expertise and specific resources.

In this paper, we aimed to follow the evolution of a subject diagnosed with Huntington's disease following the implementation of a physiotherapy program. The aim of the intervention was to monitor changes in mobility, motor control and balance following the physiotherapy program and the effects on the patient's quality of life in daily activities. Physiotherapy could contribute to reducing choreic movements, improving the patient's balance, mobility and functional autonomy. It also explores the potential of physiotherapy to slow the progression of the disease, stimulating motor and neurological functions and facilitating the patient's adaptation to the changes imposed by the condition.

MATERIAL AND METHODS

Participants

The case study is conducted on a female subject, aged 47, diagnosed with Huntington's Disease at the age of 39. 10 years ago, she presented to the county hospital in her locality in the emergency department with psychomotor agitation, behavioral disorders, insomnia and prevalent ideas. She was discharged with the diagnosis of Organic Delusional Disorder and Mental Retardation with Behavioral Disorders. After 2 years of constant hospitalizations caused by behavioral disorders and episodes of depression resulting in aggressive behavior manifested both towards those around her and towards herself, she was diagnosed with Huntington's Chorea.

In 2022, she was institutionalized in a center for the care of people with disabilities. Over time, she did not benefit from physiotherapy sessions or other forms of therapy, being prescribed exclusively drug treatment.

The therapeutic intervention was carried out with the written consent of the relatives and with the written agreement of the management of the institution where the subject is institutionalized.

Materials

The study was conducted over a period of 18 weeks, within the institution where the patient is hospitalized. After an initial assessment, therapeutic interventions were postponed for 8 weeks, providing the opportunity to observe the natural evolution of the disease. Subsequently, a personalized physiotherapy program was implemented for 10 weeks, with assessments every 5 weeks. Various assessment tools, such as Mini-Mental State Examination (MMSE), ADL Scale, Berg Scale, Tinetti Scale and Fahn-Marsden Scale, were used to monitor progress.

The physiotherapy program included prehension exercises, balance, gait and supine exercises, based on the Frenkel program. The main objectives were to improve balance, coordination, clinical manifestations, quality of life and promote independence in daily activities.

RESULTS

The 18-week study included four assessments: baseline, after 8 weeks without intervention, intermediate after 5 weeks of physiotherapy treatment and final after another 5 weeks of therapy. At the beginning, the patient had moderate balance, a medium risk of falling, a degree of assisted independence and relatively good cognitive function, but with difficulties in calculation, writing and drawing. The degree of dystonia was moderate, allowing her to carry out her daily activities. Therapeutic intervention did not begin immediately after the initial assessment due to administrative delays in obtaining the center's approval to carry out the therapy and severe depressive episodes, triggered by a family event, which affected the patient's emotional state. Under these conditions, a second assessment was carried out after 8 weeks without therapeutic intervention, which revealed that the patient's condition had worsened, with regressions in balance, memory and spatial-temporal orientation, and a high risk of falling. After 5 weeks of treatment, improvements were observed in balance, gait, mental status, and dystonia. The final assessment confirmed the progress, with significant improvement from baseline.

Berg Scale

The Berg Scale was used to assess the balance disorders of the patient in the study. The assessment was carried out in four stages, the values of each assessment are presented in the following graph (figure 1).

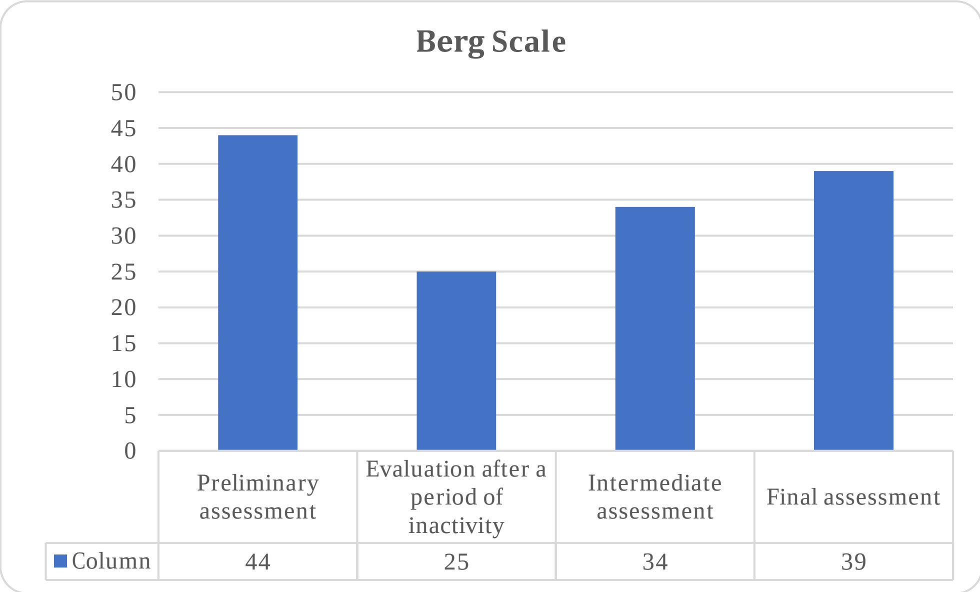

Fig. 1. Berg Scale – graphic representation
(0-20 – severely impaired balance; 21-40 – moderately impaired balance; 41-56 – almost normal balance)

The diagram highlights a severe regression of balance after the period without physiotherapy, followed by a significant improvement after 5 weeks of treatment, with continued improvements in the following period.

Tinetti Scale

To illustrate the patient's progress during the therapeutic intervention, we used the Tinetti scale, a validated and recognized tool for assessing balance and gait. The graph below (figure 2) presents the values obtained from periodic assessments performed throughout the study.

At baseline, the patient had a Tinetti score of 19, indicating moderate balance and stability, with moderate risk of falling. After 8 weeks without therapy, the score dropped drastically to 8, reflecting significant deterioration. The physiotherapy intervention led to an increase in the score to 20 after 5 weeks of treatment and to 21 at the end of 10 weeks, highlighting an almost complete restoration of balance and stability.

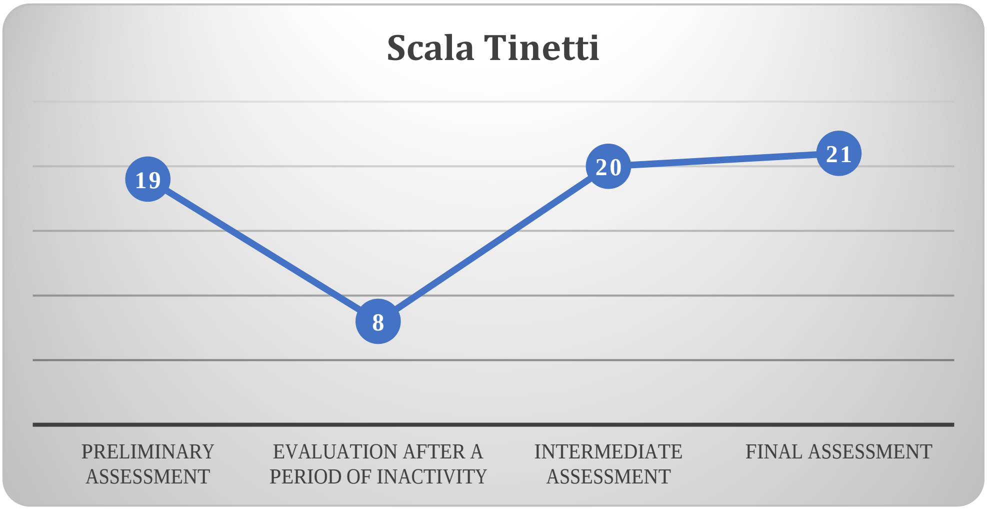

Fig. 2. Tinetti Scale – graphic representation
(< 19 – high risk of falling; 19-20 – moderate risk of falling; > 25 – low risk of falling)

MMSE (Mini Mental State Examination)

The patient's cognitive function was assessed with the MMSE, and the graph (figure 3) illustrates the evolution of the scores, highlighting the changes during the therapeutic intervention.

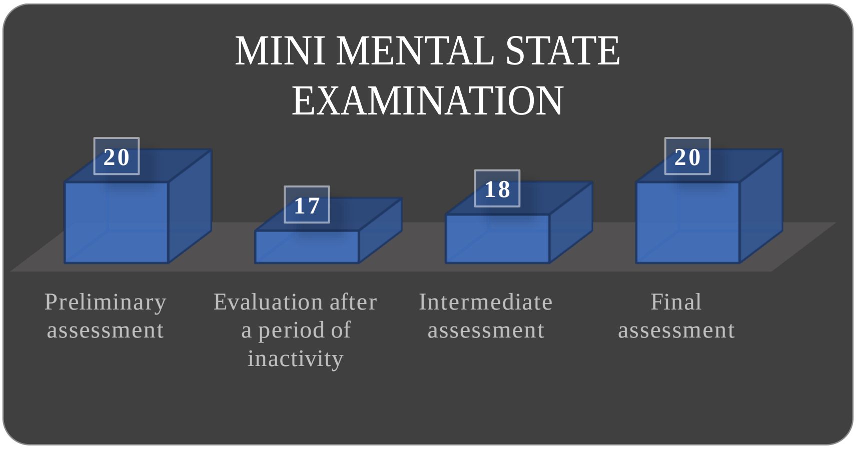

Fig. 3. Mini Mental State Examination – graphic representation
(> 21 mild cognitive dysfunctions; 0-20 moderate cognitive dysfunctions;
9 severe cognitive dysfunctions)

At baseline, the patient had an MMSE score of 20, indicating mild cognitive impairment. The score had decreased to 17 before therapy, reflecting deterioration with disorientation and difficulty following commands. After physiotherapy, the score increased to 18 and eventually returned to 20, indicating restoration of baseline, with improvements in orientation, information retrieval, and language. Attention, calculation, and writing remained impaired.

Activities of Daily Living (ADL) Scale

The data collected during the assessment of activities of daily living are illustrated in figure 4.

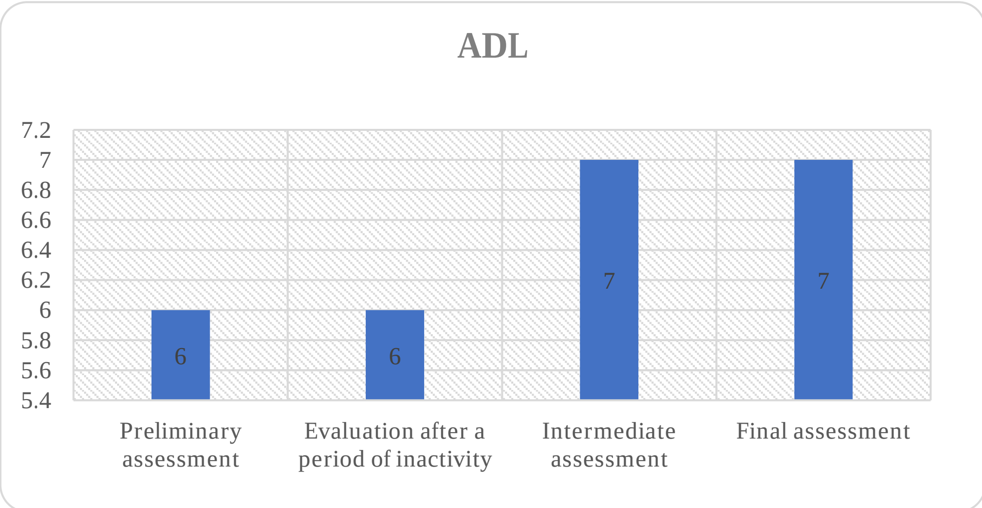

Fig. 4 ADL scale – graphic representation
(10 – autonomy; 8-10 – quasi-dependent; 3-8 – assisted independence; 0-3 – total dependence)

At the initial assessment, the patient obtained a score of 6, indicating assisted independence. The score remained unchanged before therapy. After the physiotherapy intervention, the score increased to 7, with improvements in personal hygiene, where she went from total dependence to partial help. The score was maintained at 7 at the final assessment, highlighting a modest but significant progress for quality of life.

Fahn-Marsden Scale

To assess the severity and frequency of involuntary movements in the patient in the study, we used the Fahn-Marsden scale, a specialized instrument for measuring the degree of dystonia. The values obtained from the assessments with the Fahn-Marsden scale are presented in figure 5.

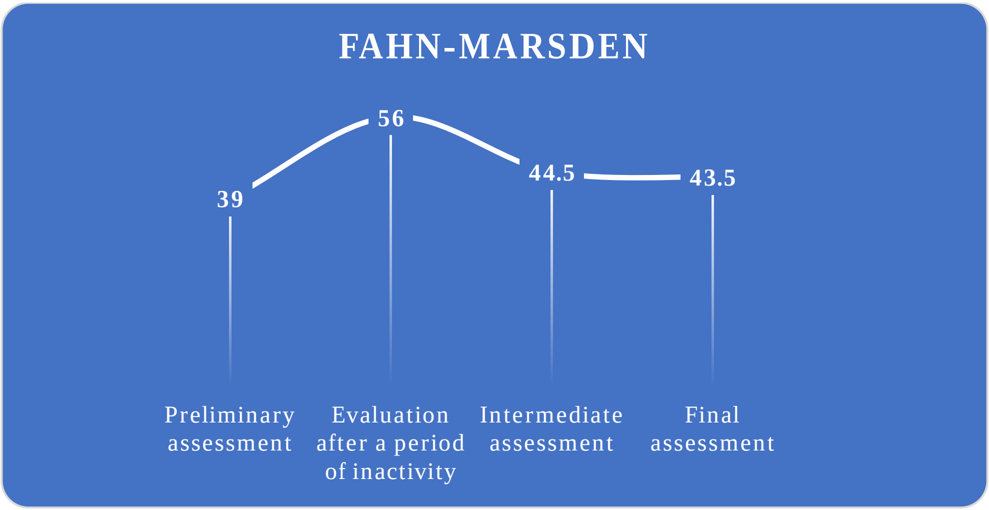

Fig. 5 Fahn-Marsden scale – graphic representation

At the initial assessment, the score of 39 indicated a moderate degree of dystonia, without major impact on daily activities. The score increased to 56 before therapy, reflecting a significant worsening. After physiotherapy, at the intermediate assessment the score decreased to 44.5, and at the final assessment to 43.5, indicating a progressive improvement in movement control and frequency of dystonic episodes.

DISCUSSION

Patients with Huntington's Disease suffer from involuntary movements (chorea), coordination difficulties, speech and swallowing problems, cognitive decline and significant personality changes; symptoms that progressively worsen, affecting daily activities and independence. The present study demonstrates the positive effects of physiotherapy on the patient studied.

At the initial assessment, the patient presented good balance (Tinetti score 19), assisted independence (ADL score 6), moderate cognitive function (MMSE 20) and moderate dystonia (Fahn-Marsden 39). After 8 weeks without intervention, the condition deteriorated: Tinetti score 8, MMSE 17, Fahn-Marsden 56, while ADL remained constant at 6, demonstrating a deterioration in balance, gait, cognitive function and a worsening of dystonic manifestations.

The physiotherapy intervention had a positive impact on the patient's condition. After the first 5 weeks of treatment, interim assessments showed significant improvements: the Tinetti score increased to 20, the MMSE to 18, and the Fahn-Marsden decreased to 44.5. These changes suggest an improvement in balance, gait, cognitive function, and dystonic manifestations. The ADL scale showed a slight improvement, with the score increasing to 7, reflecting a greater capacity for self-care, especially in the personal hygiene category. Progress continued in the following weeks, with results highlighting improvements in balance, motor, and cognitive function, with a positive impact on quality of life.

These findings are supported by the literature. Quinn et al. (2014) demonstrated that regular physiotherapy intervention reduces the risk of falls and improves motor and cognitive function. Chang et al. (2012) highlighted the role of structured physical exercise in preventing cognitive decline in elderly patients with neurological disorders. Piira et al. (2014) also showed that long-term multidisciplinary programs can improve gait, balance, and psychological well-being in patients with Huntington's disease, although the effects on cognitive function and ADL are minor.

Limitations of the study include the institutionalization of the patient, which may influence the results, and the fact that the research focused on a single case, restricting the generalizability of the conclusions. Also, the short period of therapy limits the observation of long-term effects. Future studies will explore multidisciplinary interventions to obtain more relevant results regarding the comprehensive management of this condition.

CONCLUSIONS

Huntington's disease is a progressive neurodegenerative disorder that affects motor, cognitive and mental functions, having a significant impact on the autonomy and quality of life of patients, but also on caregivers. Physiotherapy plays an important role in the management of this disease, providing benefits such as improved balance, coordination and reduced risk of falls, thus maintaining a degree of independence in daily activities.

The effectiveness of physiotherapy intervention was demonstrated by significant improvements in balance and gait (measured by the Berg and Tinetti scales), reduction of dystonia (Fahn-Marsden Scale) and stabilization of cognitive functions. The intervention also led to an improvement in orientation, language and the ability to reproduce information, contributing to better autonomy and quality of life.

In the absence of physiotherapy, rapid progression of the disease was observed, manifested by the degradation of motor and cognitive functions, highlighting the need for constant treatment. Through personalized exercises, physical therapy slows functional decline, stimulates neural connections, and provides psychosocial support, reducing anxiety and isolation.

Physical therapy is essential in the management of Huntington's disease, bringing significant physical, cognitive, and emotional benefits, supporting families and caregivers in managing daily tasks.

AUTHOR CONTRIBUTIONS

Conceptualization and methodology RMG and AMV; planning the therapeutic intervention AMV and CMP; investigation RMG; implementing the therapeutic intervention RMG; writing and data analysis RMG, AMV and CMP. All authors contributed equally to this article.
All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ANALYSIS OF CHOICE REACTION TIME IN ADOLESCENT RUGBY PLAYERS: A PILOT STUDY

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ABSTRACT. *Background*: The aim of this paper is to investigate the choice reaction time in the upper and lower limbs in adolescent rugby players, both girls and boys. *Materials and Methods*: In this study, the reaction time of 113 adolescent rugby players was investigated, including 55 players in the U13 age category—10 girls and 45 boys—and 58 players in the U15 age category—12 girls and 46 boys. The choice reaction time of the players' upper and lower limbs was evaluated using the T-Reaction software. *Results*: The results suggest that there are statistically significant differences between the mean values obtained in the two age categories, U13 and U15 ($p < 0.05$), and there are no statistically significant differences between the mean values obtained for the dominant and non-dominant upper and lower limbs ($p > 0.05$). *Conclusions*: The results suggest that there are certain significant differences in the reaction time of the upper and lower limbs, both in terms of age category and the athletes' gender. Additionally, concerning the dominant and non-dominant limbs, the reaction times are similar, with no statistically significant differences identified between them.

Keywords: reaction time; adolescent; rugby

INTRODUCTION

Reaction time (RT) is a key factor in sports performance, defined as the time from stimulus appearance to response (Kuang, 2017). It depends on the sensorimotor cycle, including stimulus detection, nerve signal transmission, CNS response generation, and movement execution (Adleman et al., 2016; Greenhouse et al., 2017; Sant'Ana et al., 2016).

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Simple reaction time is the interval from stimulus appearance to response, while complex reaction time requires identifying and selecting a response among multiple stimuli (Jayaswal, 2016). Attention influences reaction time by regulating activation, selection, and distribution of cognitive resources (Leckie et al., 2014).

Physiologically, visual reaction time involves the retina, visual pathways, motor cortex, and cerebellum, and varies with age, training, and fatigue. Simple reaction time is useful for selection and monitoring fatigue, while complex reaction time can be improved through training (Cojocariu & Honceriu, 2011; Cojocariu, 2011).

Human reaction time (RT) is influenced by age, gender, handedness, vision, practice, fatigue, exercise, personality, and intelligence (Jain et al., 2015). Its components, mental processing, nerve conduction, movement analysis, and device response, are affected by age, training, biological rhythm, and health (Cojocariu & Honceriu, 2011; Balakrishnan et al., 2014; Darbutas et al., 2013; Badau et al., 2014; Abbasi-Kesbi et al., 2017).

Studies show that reaction time can be improved through physical and sports activities, which train this ability (Jain et al., 2015; van de Water et al., 2017; Walton et al., 2018; Lynall et al., 2018). Exercise also enhances cognitive functions and attention (Reloba-Martínez et al., 2017).

Reaction time is a relevant component both in individual sports such as swimming and athletics (Nuri et al., 2013; Tønnessen et al., 2013), but this is essential in collective sports and with direct adversity, because athletes have to make quick decisions to be successful in their actions (Ruschel et al., 2011; Mudric et al., 2015).

Research in the field states that reaction time improves with age (Adleman et al., 2016) through adequate training, which is justified by the maturation of the central nervous system (Hülsdünker et al., 2018).

In performance sports, especially open-skill ones, quick decision-making and movement execution are crucial. Research shows no major differences in movement speed across skill levels, suggesting that physical ability alone isn't decisive (Djaoui et al., 2017; Kempton et al., 2017). Instead, cognitive processing speed and accurate interpretation of environmental information are key for optimal performance (Light et al., 2014; Roca et al., 2016; Hayashibe & Shimoda, 2014).

Memory and attention help athletes process information faster by improving focus and information discrimination. Technological tools and structured training protocols have been developed to measure and enhance perceptual-cognitive abilities in sports practice (Clark et al., 2015; Broadbent et al., 2015; Khanal, 2015; Parsons et al., 2014).

Reaction time is a physical ability closely linked to attention and varies with stimulus type, body state, and sensory modality (Reigal et al., 2019; Jiménez & Silva, 2018). A study on 31 teenagers found a moderate correlation between reaction time and attention capacity (Huerta Ojeda et al., 2022).

Studies have shown that there are significant differences in terms of reaction time to visual stimuli between men and women (Huerta Ojeda et al., 2022). Also, studies have shown that those who practice sports activities obtained better reaction time results compared to those who do not practice sports (Szabo et al., 2021).

In performance sport, decision making involves selecting the correct option to perform an action effectively. Although there are studies that suggest that the reaction time of the left upper limb is better compared to that of the right limb (Al-Hashel et al., 2016), there are also authors who demonstrate the opposite (Asai et al., 2010). There are also studies that state that men have better results in terms of reaction times compared to women (Nikam & Gadkari, 2015).

A separate study examined the reaction times of elite male taekwondo and kickboxing athletes, with an average age of 17, and found that the auditory reaction time of taekwondo athletes using their dominant hand was faster than that of kickboxing athletes (Çimen Polat et al., 2018).

A study on athletes from various sports (boxing, gymnastics, judo, karate, wrestling, taekwondo) found faster simple reaction times with the left hand, but better recognition and cognitive reaction times with the right hand, regardless of dominance. Reaction times were influenced by laterality, stimulus type, and sport practiced (Badau et al., 2018).

A study on 15-year-old boys and girls found that boys had faster reaction times in both hands than girls, and for both sexes the right hand was quicker than the left. Reaction time was shown to vary with age, gender, and intellectual traits (Taskin, 2016).

A study on 10-12-year-old students found that simple and complex reaction times are linked to weekly physical activity, as well as to physical fitness, attention, and concentration (Zwierko et al., 2014; van de Water et al., 2017; Westfall et al., 2018).

Another study aimed to compare the reaction times of the dominant hand among karate athletes based on age, gender, and skill level. The results revealed significant differences in both simple and complex reaction times across the three categories, children, juniors, and seniors. It was also concluded that male athletes tend to have better reaction times and faster decision-making abilities, which can be improved with practice (Coşkun et al., 2014).

Studies indicate that choice reaction time to visual stimuli is key in contact sports and can be improved through training. Research on students and judo athletes found no significant differences between athletes and non-athletes, or between dominant and non-dominant hands (Cojocariu & Abalasei, 2014).

In many sports such as football, handball or rugby, the defenders have to anticipate the movements of the opponents with the help of visual information, before the attacker changes the running direction (Runigo et al., 2010), developing in this sense anticipation skills through specific experiences from training but also from the field, studies demonstrating that experienced athletes generally obtained a better reaction time than beginner players (Fujii et al., 2014).

Rugby requires bilateral skills since players run forward but pass backward. Successful passing also depends on reactive agility, as players may need to quickly adjust planned actions. Thus, passing skill tests should include a cognitive component for validity (Pavely et al., 2009).

A developmental study on reactive agility in netball revealed that reactive agility testing was more effective in distinguishing between highly skilled and less skilled groups (Farrow et al., 2005). The quicker decision-making and movement times demonstrated by more experienced players in both pre-planned and reactive agility tests were later confirmed by a study on reactive agility in rugby league players (Gabbett & Benton, 2009).

A study on elite rugby players showed that dominant-side reaction times were faster than non-dominant, and skilled players had quicker decisions and movements without losing accuracy. Their superior anticipation indicates a greater ability to extract relevant visual information, highlighting the usefulness of reactive agility tests for evaluating perceptual agility (Gabbett & Benton, 2009).

A study on national rugby players tested a neurocognitive training program designed to improve visual perception, information processing, and decision-making. Results showed that perceptual-cognitive training is essential in open-skill sports, where performance depends not only on physical abilities but also on the ability to interpret and react quickly to game situations (Moya-Vergara et al., 2019).

Research shows that expert rugby players have faster and more accurate reaction times than intermediate or novice players. Differences across skill levels and ages suggest that extensive sport-specific experience develops perceptual expertise (Gabbet & Abernethy, 2013).

MATERIAL AND METHODS

The aim of this paper is to investigate the choice reaction time in the upper and lower limbs in adolescent rugby players, both girls and boys.

We hypothesize that there are statistically significant differences between the U13 and U15 age categories in terms of choice reaction time development. Additionally, we hypothesize that we will identify statistically significant differences in the choice reaction time values between dominant and non-dominant upper and lower limbs.

Participants

In this study, the choice reaction time of 113 adolescent rugby players was investigated, including 55 players in the U13 age category—10 girls and 45 boys—and 58 players in the U15 age category—12 girls and 46 boys. It is important to note that the data is analyzed based on age category, not gender, as rugby teams in these two age groups are mixed, comprising both girls and boys. The study was approved by the Ethics Committee, and informed consent was obtained from all participants prior to their inclusion in the research.

Procedure and materials

The choice reaction time of the players' upper and lower limbs was evaluated using the T-Reaction software (Cojocariu, 2011), through two tests, with the implementation protocol de-scribed below. The subject is seated with their hands positioned above the keyboard, fingers close together, and the look directed at two circles on the screen. When the colour of one of the circles changes, the subject must press the right or left key as quickly as possible, depending on the location of the stimulus. The test involved 20 executions over one minute, with a 2-second interval between each, and the arithmetic mean of the dominant and non-dominant hand executions was calculated. The same protocol was applied in evaluating the reaction time of the lower limbs, with the subject seated comfortably in a chair, feet positioned above the two keyboards. We chose to use two stimuli in testing complex reaction time because, in rugby, situations may arise where a player needs to avoid contact with an opponent by moving to the left or right, or situations where a player must receive the ball from a teammate coming from one side or the other.

Data analysis

The statistical analysis was conducted using the SPSS IBM Statistics V20 software, performing statistical tests such as the Shapiro-Wilk test to check the normality of the data distribution, the one-way analysis of variance (ANOVA) to identify statistically significant differences in the mean values between groups based on the gender and age of the athletes, the Independent Samples T test to determine the differences between the two age categories in mean values, and the Paired Samples T test to identify differences between the dominant and non-dominant limbs of the players.

RESULTS

Following the application of the Shapiro-Wilk statistical test, we observe that the data regarding the choice reaction time of the upper and lower limbs for the players has a nor-mal distribution, with a p-value greater than 0.05 in both the U13 age category and the U15 age category for both girls and boys.

According to Table 1, following the application of the Independent Samples T test, we observe statistically significant differences between the mean values obtained in the two age categories, U13 and U15, regarding choice reaction time in the upper and lower limbs, as indicated by the significance threshold p value being less than 0.05. As is natural, with the processes of growth and development, there is also a notable enhancement in cognitive processes, such as attention and speed of thought, as well as neural processes during this maturation period, which may explain the highlighted differences.

Table 1. Statistical differences between the two age categories, U13 and U15

	U13 (N=55)			U15 (N=58)			
	Mean		**Std. Dev.**	**Mean**		**Std. Dev.**	**P**
CRT NON-DOMINANT UPPER LIMB	465.81	±	56.53	401.57	±	40.15	**0.000**
CRT DOMINANT UPPER LIMB	478.54	±	59.07	408.84	±	39.87	**0.000**
CRT NON-DOMINANT LOWER LIMB	496.14	±	75.97	436.63	±	46.40	**0.000**
CRT DOMINANT LOWER LIMB	494.50	±	77.53	432.57	±	57.48	**0.000**

**CRT= choice reaction time*

After applying the Paired Samples T test, according to table 2, we observe that there are no statistically significant differences between the mean values obtained for the dominant and non-dominant upper limbs, nor between the mean values for the dominant and non-dominant lower limbs, with p values greater than 0.05.

Table 2. Statistical differences between dominant and non-dominant limbs, both upper and lower

		U13 (N=55)				U15 (N=58)			
		Mean		**Std. Dev.**	**P**	**Mean**		**Std. Dev.**	**P**
P1	**CRT NON-DOMINANT UPPER LIMB**	465.81	±	56.53	0.062	401.57	±	40.15	0.182
	CRT DOMINANT UPPER LIMB	478.54	±	59.07		408.84	±	39.87	
P2	**CRT NON-DOMINANT LOWER LIMB**	496.14	±	75.97	0.838	436.63	±	46.40	0.537
	CRT DOMINANT LOWER LIMB	494.50	±	77.53		432.57	±	57.48	

**CRT= choice reaction time*

This can be explained by the fact that the athletes undergo comprehensive training, utilizing both dominant and non-dominant limbs with equal efficiency during gameplay. Additionally, in rugby, technical skills such as passing and catching the ball, tackling, throwing in from the sideline, and clearing the ball involve the use of both upper limbs.

Also, following the application of the one-way analysis of variance, no statistically significant differences were identified between girls and boys in the U15 age category, with the significance threshold being greater than 0.05.

In the U13 age category, statistically significant differences were found in the choice reaction time of the non-dominant upper limbs with $p = 0.044$, the dominant upper limbs with $p = 0.005$, and the non-dominant lower limbs with $p = 0.001$. However, for the choice reaction time of the dominant lower limbs, the average values between girls and boys were similar ($p = 0.170$).

DISCUSSION

The average results obtained by participants for upper limbs were analyzed by age and gender, with approximate values as follows: U13 boys- 460 ms, U13 girls- 500 ms, U15 boys- 405 ms, U15 girls- 408 ms. Thus, we observe an improvement in choice reaction time with age, with statistically significant differences identified between the two age groups ($p=0.000$), an aspect also supported by the specialized literature (Cereatti et al., 2009). In rugby, this aspect has been studied from another perspective, specifically based on game experience, with differences found between novice and elite players (Gabbett & Abernethy, 2013). This could serve as a future research direction, potentially analyzing adolescent rugby players based on their years of experience in the sport. Choice reaction time may yield better results as age increases, due to the physical and cognitive growth and development processes they undergo.

Regarding gender differences, in our study, statistically significant differences were highlighted between girls and boys only in terms of the choice reaction time of the upper limbs, in the U13 age category ($p<0,05$). In this regard, there are studies indicating differences between men and women in the development level of reaction time to visual stimuli (Huerta Ojeda et al., 2022; Szabo et al., 2021), with men showing better results than women (Nikam et al., 2015; Taskin, 2016; Coşkun et al., 2014). However, we interpret our data with caution, as the number of girls is considerably lower than that of boys in both age categories. This is due to the fact that, in these age groups, rugby XV is played in mixed teams, and the number of female players is generally smaller, which may represent a limiting factor in our study.

Additionally, no differences in reaction time were identified between the dominant and non-dominant limbs of the evaluated players ($p>0.05$). This may be explained by the fact that rugby players undergo comprehensive training, preparing them to make contact or evade opponents from both sides, as well as to receive the ball from teammates on both the dominant and non-dominant sides. However, there are authors who have identified significant differences between the reaction time of dominant and non-dominant limbs among elite rugby players (Gabbett & Benton, 2009), therefore, we consider it necessary to study this skill in more detail across other age categories or different levels of playing experience.

Since we did not find specialized studies analyzing reaction time in the lower limbs, the obtained data cannot be compared or discussed; however, they may be analyzed in future scientific articles.

CONCLUSIONS

This study was based on two main hypotheses: first, that there would be identifiable differences in players' reaction times based on gender and age category, and second, that there would be identifiable differences in reaction times between dominant and non-dominant, upper and lower limbs.

In this regard, the statistical analysis demonstrated that the choice reaction time of players in the U13 age category is significantly higher than that of players in the higher age category. Additionally, concerning the dominant and non-dominant limbs, the reaction times are similar, with no statistically significant differences identified between them. Regarding gender differences, some variations were found in the U13 age category, which could be further explored in the future.

Thus, we can conclude that the research results confirm the first hypothesis, identifying differences in the reaction time of rugby players' upper and lower limbs based on age category and gender. Regarding the second focus of the study, the results disprove the proposed hypothesis, as no statistically significant differences were found between the dominant and non-dominant limbs of the rugby players.

We consider the analysis of choice reaction time among rugby players to be important because, during the game, they must respond quickly to various stimuli that may arise on the field. Good reaction time can facilitate the rapid execution of game phases and the effective performance of technical actions specific to rugby.

We consider it necessary to investigate choice reaction time in senior teams as well, including a larger sample of both female and male players. Additionally, another perspective would be to analyze this parameter in association with players' ability to change direction in response to a stimulus, as this reflects a more field-applicable situation.

AUTHOR CONTRIBUTIONS

All authors have equal contribution.

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THE IMPACT OF BODY WEIGHT ON POSTURAL MALALIGNMENT

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ABSTRACT. This study aims to evaluate the impact of body weight on postural malalignment among a group of 82 participants, all employed by Ministry of Internal Affairs in Romania. Postural malalignment was assessed in the orthostatic position, in the sagittal plane, on the dominant (right) side. Joint angle values were determined using a goniometer, and the length of the thoracic spine was measured with a metric tape and the body weight with a electronic scale. Descriptive statistical analysis of the data, performed using SPSS software, indicated that the most significant weight ranges for the prevalence of malalignment were 86 kg (4.9%) and 90 kg (6.1%), suggesting a tendency for postural deviations in cases of higher body weight. Weights below 60 kg were very rare (1.2%), indicating a minor representation of individuals with low body weight within the subject group. Spearman correlation analysis revealed the existence of significant relationships between body weight and certain postural angles, suggesting that body mass is positively and significantly correlated (p=0.00) with the craniovertebral angle and the knee flexion angle. This supports the idea that individuals with higher weight exhibit evident postural adaptations in these segments, a phenomenon interpreted as a strategy to compensate for the displacement of the centre of gravity. Higher body weight was also associated with an elongation of the thoracic spine, perceived as an adaptive reaction to changes in body alignment and mass distribution, contributing to the support of body weight and postural stability. The absence of significant correlations between shoulder position and knee flexion, as well as between pelvic tilt and knee flexion, demonstrates that postural adaptation mechanisms can act selectively on certain muscle chains, without always involving the entire locomotor system. Furthermore, correlation analysis highlighted several significant relationships between postural parameters, revealing a complex model of biomechanical interdependence. The forward position of the head is directly

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correlated with the forward position of the shoulders, confirming existing theories on ascending kinematic chains, according to which changes in head position induce adaptations at the level of the scapular girdle. Consequently, the research findings support the concept of postural interdependence between the upper and lower body segments. The significant correlations identified between alignment parameters demonstrate the existence of an integrated dysfunctional model, where adaptations in one segment generate compensatory changes in global postural alignment.

Keywords: body weight, postural malalignment, body postural angles, postural adaptation.

INTRODUCTION

Postural malalignments among police officers can lead to biomechanical imbalances, chronic musculoskeletal pain and reduced mobility, thereby affecting both health and operational performance. In the absence of specific data regarding employees of the Ministry of Internal Affairs (M.A.I) and the scarcity of studies relevant to the Romanian context, preliminary investigations are essential to determine the magnitude and severity of the problem, thereby facilitating the prevention of related risks, injuries, functional impairments, and occupational incapacity.

Studies of Yip et al. (2008) and Quek et al. (2013) have highlighted a functional relationship between the anteriorization of the head and the position of the shoulder girdle, supporting the idea of an interdependent postural chain between the head, neck and shoulders. Sustained efforts of the cervical muscles can lead to localized fatigue and accentuation of the curvature of the spine in this segment, thus affecting cervical alignment by altering the cranio-vertebral angle (Waersted et al., 2010; Zhou et al., 2024).

Malalignment of the knee and pelvis generates a functional imbalance, which overloads the lumbosacral region, thus supporting the link between poor segmental alignment (Hofste et al., 2021; Simonet et al., 2020). Ohko and Ota (2023) point out that biomechanical changes, especially those related to knee flexion can negatively influence the postural alignment of the lower limb, thus strengthening the hypothesis of postural adaptation. The study by Downie et al., (2025) supports the idea that accentuated knee flexion is a compensatory strategy for maintaining balance, especially in the context of biomechanical limitations.

Kett et al., (2021) highlighted the fact that changes in postural alignment, especially in the lumbar and thoracic area, can cause an increase in muscle stiffness and loads on the spine, depending on the supported positions and morphological characteristics of the individual. Thus, the length of the body segments and the positioning of the center of gravity can lead to compensatory adjustments of the position of the head and knees, visible at the larger angles observed.

Overall, these results reflect the complexity of the interactions between body morphology and postural adaptations.

The purpose of this research was to analyze the prevalence of postural malalignment among the Romanian police workers, identifying the associated risk factors like the body weight, in order to validate proposals for preventive and corrective measures aimed at improving physical functionality and professional efficiency.

The objective was to detect how the body weight influence the prevalence of postural malalignment, by analyzing and interpreting the collected data, in order to identify and understand the variables associated with the occurrence of this postural deviation.

MATERIAL AND METHODS

Participants

The subjects of the research are represented by police officers from the representative structures for the activity of the Romanian Border Police, employees of the Ministry of Internal Affairs, who met the selection criteria to be included in the study. The participants are part of various operational work units such as: service shifts, surveillance and control, operational support, combating cross-border crime, control-access, which carry out activities in the field for the surveillance and control of the state border, in fixed points for guarding objectives, patrols, control of persons, cars and documents, in traffic or participate in interventions, but also with non-operative specificity: administrative offices, logistics, secretarial, procurement, finance, communications and training departments within the Initial and Continuous Training School of the Border Police, representing a wide spectrum of roles within the Border Police. Subjects of both genders and different age groups reflect the actual composition of M.A.I. employees, which reduced the possibility of selection bias. This ensures that the study group is not limited to just certain types of employees and is representative of the entire institution.

Participants were informed about the objectives of the study and the purpose of the research, the procedures involved, including data collection methods, biomechanical measurements and the right to be able to withdraw at any time without negative consequences. Subjects gave their consent to participate freely, informedly, and voluntarily in the research by signing a standardized consent form that included the statement of consent, confirmation that they understood the purpose and methods of the study, consent to the anonymous use of the data collected, and details about the preservation of confidentiality.

Considering that the participants are employees of the Ministry of Internal Affairs, the official approval was requested from the director of the Initial and Continuous Training School of the Border Police of Iasi and the Head of the Territorial Inspectorate of the Border Police of Iași, for which inter-institutional collaboration contracts were made and compliance with the internal regulations on investigations involving the personnel of the Ministry of Internal Affairs was ensured.

At the beginning of the study, we considered a number of 237 police workers, but following the application of the selection criteria, the number of subjects was reduced to 150 participants. *Inclusion criteria:* active employees within the Ministry of Internal Affairs; availability for voluntary participation; age between 20 - 55 years; each participant held the approval of the unit doctor, confirming their medical fitness for engaging in physical effort. *Exclusion criteria:* history of severe neurological disorders or structural deformities of the musculoskeletal system, of recent spine or joint surgery; lack of consent to participate, including refusal or omission to sign the informed consent document.

Based on the assessment of postural malalignments conducted through standardized measurement protocols, 82 of the 150 participants exhibited deviations from the optimal body angle values.

Procedure

The measurement procedures were performed during the period February–April 2025, in the gym of the Initial and Continuous Training School of the Iasi Border Police, under the same conditions for all participants. The subjects were instructed to maintain an orthostatic position characterized by a natural and comfortable posture throughout the evaluation process. A laser pointer helped maintain eye level through a dot marked directly in front of each participant. We determined the cranio-vertebral angle (icva), the forward shoulder angle (ifsa), the pelvic tilt angle (ipt) and the knee flexion angle (ikf), in the sagittal plane, on the dominant side (right) and measured it in degrees. Estimation of thoracic kyphosis was summarized to measuring the curvature of the thoracic spine in centimeters, and weight was measured in kilograms.

Ideal postural alignment angles values are: cranio-vertebral (icva) = 55°, shoulder alignment (ifsa) = 0°, pelvic angle (ipt) = 0–15°, and knee flexion (ikf) = 0–10°, ensuring proper spinal alignment and weight distribution (Magee & Manske, 2021).

Materials

The evaluation of anatomical body angles was performed with the goniometer, utilized as a precise instrument for quantifying postural malalignments, that reproduces the degrees of inclination between two body segments. The assessment of thoracic kyphosis was conducted using a metric measuring tape, whereas body weight was determined with a calibrated electronic scale.

Data analysis

For the analyses we used SPSS software, version 20 ($\alpha = 0.05$). The Shapiro – Wilk Test was used to assess the normality of the data distribution in our group of subjects. The Sig. value $p = 0.009$, lower than 0.05, suggests rejecting the hypothesis of normality.

RESULTS

Based on the statistical analysis and the graphical representations in Figure 1 (histogram and boxplot of the body weight variable generated in SPSS), the body weight of police officers exhibiting postural malalignments was found to range from 56 kg to 108 kg, reflecting a relatively wide dispersion of values across the sample. The most frequently body weight reported among the subjects associated with postural malalignment was recorded at 90 kg, followed by 86 kg, both values with percentages of 6.1% and 4.9%, respectively. Other commonly encountered body weight ranges are 64 kg, 74 kg and 94 kg, each with a percentage of 3.7%. The most common weight ranges: 90 kg (6.1%) and 86 kg (4.9%) are the most represented, suggesting a higher prevalence of malalignment in police officers with higher body weights. Weights under 60 kg are very rare, with only 1.2% of police officers weighing 56 kg, indicating a minor representation of those with low weight within the group of subjects. The majority (67.1%) have a body weight of less than 90 kg, while only 32.9% are equal to or above 90 kg.

This distribution suggests that, within this group affected by malalignment, subjects with higher body weight are not predominantly represented. The Chi-square test was used to examine whether the proportions of subjects with malalignment differ significantly based on body weight categorized below and above 90 kg. The results show a statistically significant difference between the two groups, $\chi^2(1) = 9.561$, $p = 0.002$, the number of those weighing less than 90 kg is significantly higher.

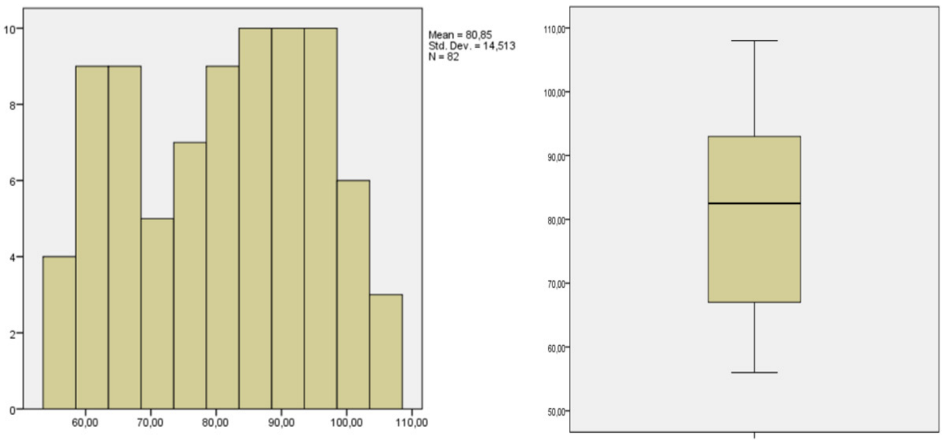
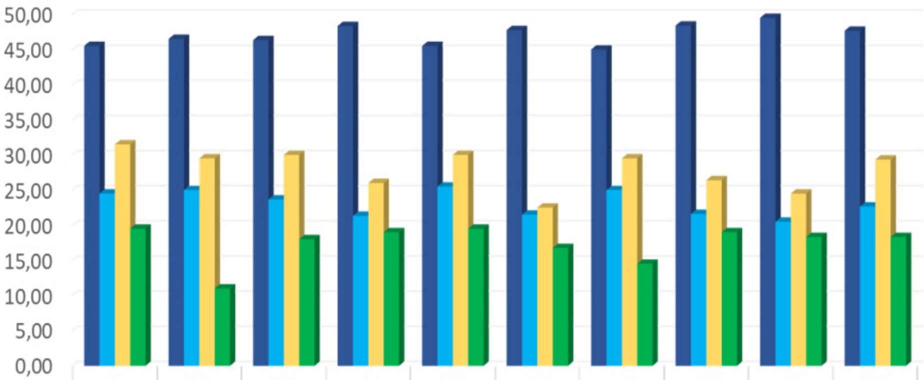


Fig. 1. Histogram and boxplot of the variable body weight according to SPSS

Fig.2 illustrates the comparative graph for the distribution of the average values of the body angles of the subjects with misalignments, according to weight. Spearman's analysis of correlations reveals significant relationships between body weight and certain postural angles, suggesting that body mass may influence the alignment of body segments.



	67	70	74	80	84	86	89	90	97	102
icva	45,50	46,50	46,33	48,33	45,50	47,75	45,00	48,40	49,50	47,66
ifsa	24,50	25,00	23,66	21,33	25,50	21,50	25,00	21,60	20,50	22,66
ipt	31,50	29,50	30,00	26,00	30,00	22,50	29,50	26,40	24,50	29,33
ikf	19,50	11,00	18,00	19,00	19,50	16,75	14,50	19,00	18,33	18,33

Fig. 2. Distribution of body angle values according to body w eight

The results, according to Table no.1, highlight a moderate positive correlation between body weight and cranio-vertebral angle (icva), with a coefficient of 0.536 and a significance level of p = 0.000. A higher body weight may be associated with increased muscle mass among our subjects, which could explain the lower prevalence of postural malalignments observed in police officers weighing more than 90 kg. These findings indicate that police officers with lower body weight are more likely to present a forward head posture, which may represent a biomechanical adaptation associated with inadequate muscle development.

According to Table no.1, a moderate and significant positive correlation between body weight and knee flexion angle (ikf) is also observed, with a coefficient of 0.547 and p = 0.000, suggesting that heavier police officers may exhibit accentuated knee flexion in a static position, presumably to maintain stability and balance.

Table 1. Spearman's correlations between the independent variable body weight and dependent variables: body angles and spine length.

Variable	Weight	Icva	Ifsa	Ipt	Ikf	Iky
Weight	1.000	0.536**	-0.164	-0.138	0.547**	0.799**
p	-	0.000	0.141	0.215	0.000	0.000
Icva	0.536**	1.000	-0.404**	-0.251*	0.339**	0.256*
p	0.000	-	0.000	0.023	0.002	0.020
Ifsa	-0.164	-0.404**	1.000	0.289**	0.067	0.076
p	0.141	0.000	-	0.008	0.550	0.499
Ipt	-0.138	-0.251*	0.289**	1.000	0.113	-0.175
p	0.215	0.023	0.008	-	0.313	0.116
Ikf	0.547**	0.339**	0.067	0.113	1.000	0.524**
p	0.000	0.002	0.550	0.313	-	0.000
Iky	0.799**	0.256*	0.076	-0.175	0.524**	1.000
p	0.000	0.020	0.499	0.116	0.000	-

**Correlations are significant at the level of 0.05 (2-tailed).*
***Correlations are significant at the level of 0.01 (2-tailed).*

The forward shoulder angle (ifsa) and the pelvic tilt angle (ipt) do not have significant relationships with body weight, having coefficients of -0.164 (p = 0.141) and -0.138 (p = 0.215), according to Table no.1, which suggests that these postural components are not directly influenced by body weight, but rather by other functional factors or specific to professional activity.

Fig.3 shows the comparative graph for the distribution of the mean values of the length of the thoracic spine, of the subjects with malalignments, according to the weight variable.

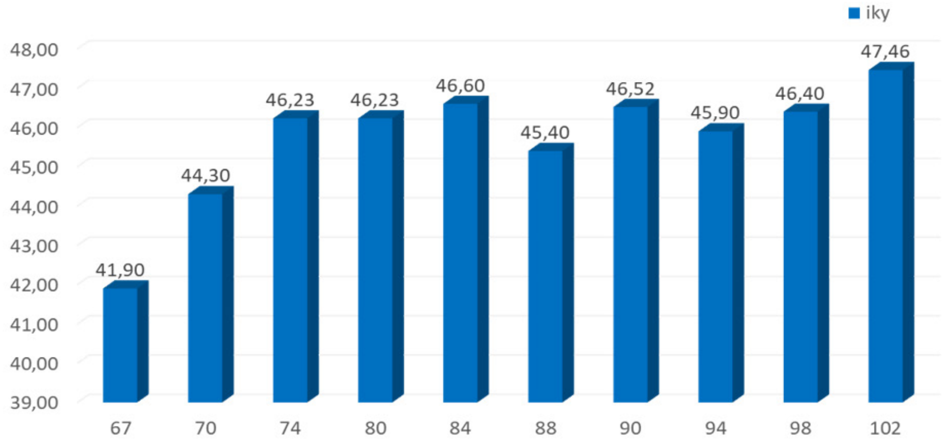


Fig. 3. The length of the thoracic spine according to body weight.

Analysis of the Spearman correlation between body weight and thoracic spine length (iky), suggests a significant association. With a correlation coefficient of 0.799 and a significance value of p = 0.000, according to Table no.1, the results indicate a strong positive correlation between body weight and thoracic spine dimensions. This suggests that police officers with higher body weight tend to have a longer thoracic spine length, which may be interpreted as an adaptive mechanism aimed at compensating for weight distribution and maintaining postural stability.

The analysis of correlations highlighted several significant relationships between postural parameters, revealing a complex pattern of biomechanical interdependencies. In the case of the correlation between craniovertebral angle (icva) and forward shoulder position (ifsa), a strong negative association was observed with a coefficient of -0.404 ($p<0.01$), indicating that head anteriorization correlates directly with shoulder anteriorization. This finding confirms existing theories on ascending kinematic chains, according to which changes in the position of the head induce adaptations at the level of the shoulder gridle.

We identified a moderate positive correlation between craniovertebral angle and knee flexion with a coefficient of 0.339 ($p<0.01$), suggesting the existence of a compensatory mechanism by which subjects with anterior cranial position develop an accentuated knee flexion to maintain postural balance. This phenomenon can be interpreted as a strategy to compensate for the displacement of the center of gravity.

At the moderate significance threshold ($p<0.05$), the analysis revealed a negative correlation between craniovertebral angle and pelvic tilt with a coefficient of 0.251, as well as a positive relationship between forward shoulder position and pelvic tilt with a coefficient value of 0.289. These results support the concept of postural interdependence between upper and lower body segments, demonstrating how postural adaptations at one level can influence body alignment at other levels.

The analysis did not identify significant relationships (p >0.550) between shoulder position and knee flexion, respectively between pelvic inclination and knee flexion. These results may suggest that postural adaptation mechanisms may act selectively on certain muscle chains, without always involving the entire musculoskeletal system.

DISCUSSION

The findings strengthen the concept of postural interdependence between upper and lower body segments, indicating that compensatory adaptations within one region can influence the alignment and functional stability of other segments.

The significant correlations identified between body angles (craniovertebral, forward shoulder angle, knee flexion and pelvic tilt) support the existence of an integrated dysfunctional model, wherein adaptations of a segment may influence the overall postural alignment. This result corroborates existing theories regarding ascending kinematic chains, suggesting that alteration in head posture can trigger compensatory adjustments within the shoulder girdle. Moreover, these results indicate that postural adaptation mechanisms may act selectively on certain muscle chains, rather than involving the entire musculoskeletal system simultaneously.

The results indicate the existence of a compensatory mechanism through which individuals displaying an anterior cranial posture develop accentuated knee flexion as a means of preserving postural stability. This adaptation may be understood as a corrective strategy to offset the forward shift of the body's center of gravity.

The study suggests that higher body weight may reflect greater muscle mass and that, in the context of postural malalignment assessment, well-developed musculature could serve a protective function by promoting optimal biomechanical alignment and thereby reducing the risk of postural deviations.

According to the study by Ku et al. (2012), body weight exerts a notable effect on static postural control. People with higher body weight, especially those in the obesity category, have poorer postural control, which can cause biomechanical adjustments, such as a more pronounced bend of the knees, to maintain stability and balance in a static position. The research of Delgado et al., (2021) and Liew et al., (2020) support our results in the case of excess weight that influences the center of gravity and global posture, and this effect is amplified in conditions of physical effort, vicious positions and lack of neuromuscular recovery. Consequently, the study posits that postural adaptations, including increased knee flexion, may represent compensatory mechanisms aimed at mitigating the biomechanical challenges associated with body weight and preserving postural equilibrium.

CONCLUSIONS

The results indicate that increased body weight may be associated with enhanced muscle mass, potentially explaining the reduced occurrence of postural malalignments among police officers exceeding 90 kg. Conversely, those with lower body weight tend to display a forward head posture, which may reflect a compensatory biomechanical adaptation linked to suboptimal muscle development.

Body weight correlates significantly with craniovertebral and knee flexion angles, which involves obvious postural adaptations in these segments. However, the lack of significant correlations with shoulder and pelvic angles suggests that the influence of weight on posture is not uniform and may vary depending on other individual factors.

The association between higher body weight and thoracic spine elongation suggests an adaptive biomechanical mechanism through which the body compensates for changes in postural alignment and load distribution, thereby supporting overall stability and weight-bearing efficiency.

Body weight may be a determinant of the postural alignment and the results of the present study indicate an inverse association between body weight and the prevalence of postural malalignments among subjects, suggesting that higher weight associated with increased muscle mass, may contribute to enhanced postural stability and reduced malalignment risk.

AUTHOR CONTRIBUTIONS

Andreea Mihuță and Adrian Cojocariu played key roles in the design and implementation of the research, the analysis of the results, and the preparation of the manuscript. Both authors have reviewed and approved the final version of the manuscript for publication.

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MANAGEMENT OF CLASSROOM-BASED PHYSICAL EDUCATION LESSONS

Maria-Lorena MOGOȘ[1], Velu-Sebastian BARTHA[1], Remus VĂIDĂHĂZAN[2*], Ramona Ancuța NUȚ[1]

ABSTRACT. *Introduction:* In recent years, the management of physical education lessons has faced multiple challenges, particularly in situations where classes must be held indoors due to lack of facilities or unfavorable weather. The physical space of the classroom poses significant limitations, requiring teachers to adopt specific management strategies and instructional adaptations. *Objective:* The aim of this study is to analyze how physical education lessons are managed when conducted in the classroom setting. The research aimed to identify the instructional adaptations, spatial strategies and safety measures teachers employ when traditional sport facilities are unavailable, providing evidence-based insights for delivering safe and effective classroom-based physical education. *Materials and methods*: Data was collected through an online questionnaire distributed via Google Forms. The sample consisted of 17 physical education teachers from the Șimleu Silvaniei area. The questionnaire included 19 items focused on the frequency of classroom-based lessons, instructional strategies, planning methods, digital resource usage, and perceived challenges. Responses were analyzed descriptively, using tables and graphs to support interpretation. *Results*: The results indicate that most teachers frequently conduct physical education lessons in the classroom, especially at the primary level. Although only a small percentage have received formal training in this area, many express interest in professional development. The most commonly used methods include low-intensity exercises, movement adaptation, and digital tools. The main obstacle identified was the limited physical space available. *Conclusion*: The findings highlight the need for targeted training and better resource allocation to support physical education in constrained indoor environments. Effective management of such lessons depends on the teacher's ability to adapt content, use technology, and maintain student engagement despite space and other limitations.

Keywords: Physical education; lesson management; teacher competence; school facilities; classroom-based.

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INTRODUCTION

In recent decades, Physical Education (PE) has become increasingly aligned with broader educational reforms aimed at improving curricular coherence, learning quality and scholars well-being. Within this framework, PE is defined as a structured, intentional process that contributes to physical development, motor competence, health promotion and the formation of personal and social skills (Hanțiu & Stănescu, 2010). As part of the national curriculum, PE is required to fulfil formative, health-oriented and behavioural objectives, ensuring active participation and the acquisition of fundamental motor abilities.

Modern educational perspectives emphasise that learning outcomes in PE depend not only on motor content but also on the school environment, organisational quality and teaching conditions (Guo et al., 2023; Zhang et al., 2022). Research shows that the physical and organisational context of schools including: space availability, equipment, time allocation and teacher support; significantly influences scholars' physical activity and engagement levels (Blaes et al., 2013; Delidou et al., 2015; Morton et al., 2016).

In the context of European schools, there is an increasing tendency to integrate physical activity into non-traditional spaces, particularly in institutions with limited infrastructure. International studies show that movement opportunities in adapted environments can still support motor development and contribute to meeting WHO standards for children's physical activity, provided that tasks are well adjusted to the environment (Kriemler et al., 2023; WHO, 2020).

Teacher competence plays a central role in PE lesson effectiveness. Contemporary studies highlight the importance of classroom management skills, task differentiation, communication, safety protocols and adaptive teaching strategies, particularly when instruction takes place outside specialised sports environments (Botgros & Franțuzan, 2010; Grube et al., 2018; Shandi, Bakhtiar, & Mahdi, 2025). Professional competence also includes the ability to monitor progress, design developmentally appropriate tasks and maintain a motivating learning atmosphere. In modern educational management, teachers are viewed as both instructional leaders and organisational managers. The ongoing digitalisation of education provides significant support for instructional activities in physical education. Digital tools and online platforms facilitate efficient lesson planning, enable high-quality technical demonstrations, offer visual and interactive materials that strengthen conceptual understanding and foster student motivation (Manole, 2023; Țurcanu & Jurat, 2024).

In a few Romanian schools the access to sports facilities is reduced, PE is often conducted in improvised indoor spaces such as classrooms, corridors or multipurpose halls. These conditions require teachers to reorganise content, modify task complexity and apply strict safety measures (Ghidarcea, 2012). Classroom-based lessons reduce movement amplitude and teacher visibility, increasing the need for well-structured routines and spatial organisation practices (Fitzgerald & Deutsch, 2016). Research on motor learning in restricted spaces highlights the importance of micro-planning strategies, routine, and optimised teacher visibility (Hudson, 2022), which are essential for maintaining safety and lesson fluency. Furthermore, recent literature emphasises the significant role of educational technologies in providing visual support and enhancing student engagement when movement volume is inevitably reduced (Casey, Goodyear, & Armour, 2017).

Current research confirms that confined indoor environments limit movement amplitude and require teachers to select low-risk motor tasks that can be executed safely in reduced spaces (Hartikainen et al., 2023). Within these constraints, teachers can still implement applicative motor skills, simplified gymnastic elements or low-risk sport-specific tasks (such as controlled passing or dribbling) provided that space allows safe execution.

Theoretical or seminar-type lessons also represent a valuable alternative in such contexts, enabling pupils to develop cognitive competences through structured explanations, visual materials and guided discussion. Contemporary literature highlights the pedagogical value of this lesson format, emphasising its clarity, logical sequence and effectiveness in supporting conceptual understanding.

Safety remains a critical consideration when adapting PE lessons to classroom environments. Teachers may improvise with soft, lightweight or low-risk materials to minimise the likelihood of injury, while ensuring that tasks emphasise control rather than speed or force. Current evidence shows that systematic risk-management strategies and explicit safety rules significantly reduce injury risk in constrained PE settings (Fitzgerald & Deutsch, 2016).

The purpose of this study was to examine how physical education lessons can be effectively organised and managed in classroom settings with limited space. The research aimed to identify the instructional adaptations, spatial strategies and safety measures teachers employ when traditional sport facilities are unavailable, providing evidence-based insights for delivering safe and effective classroom-based physical education.

MATERIAL AND METHODS

In the study we used a descriptive, questionnaire-based design to investigate how physical education lessons are managed when they must be conducted in classroom settings. The approach combined quantitative items with open-ended questions, allowing both numerical description and qualitative insight into teachers' strategies of adaptation, space management and safety.

The research involved 17 physical education teachers from the area of Șimleu Silvaniei (Sălaj County, Romania), distributed across eight pre-university institutions: "Silvania" Gymnasium School (3 respondents), "Horea" Gymnasium School (2), "Bathory Istvan" Gymnasium School (1), the Center for Inclusive Education (1), "Simion Bărnuțiu" National College (3), "Iuliu Maniu" Technical College (1), "Ioan Ossian" Technological High School (2) and Gymnasium School No. 1 Pusta (4). These teachers formed a relatively homogeneous professional group, all specialised in physical education, and included teachers who had situations in which they were required to conduct physical education lessons in the classroom, due to the absence, distance or limited availability of outdoor/ indoor specialised sports facilities.

Data were collected using a 19-item questionnaire designed specifically for this study, adapted from the PESSEI (Physical Education and School Sport Environment Inventory) instrument, which evaluates the physical, material and organisational conditions relevant to school-based physical education, validated by Fairclough, Hilland, Vinson, & Stratton in 2012. The items were constructed based on the research objectives and relevant literature on educational management and physical education methodology. The questionnaire underwent a minimal content-validation process through consultation with two experts in physical education methodology to ensure that the items were relevant to the study's objectives. This procedure aligns with methodological recommendations for adapting research instruments to specific contexts (Boateng et al., 2018).

The questionnaire included: introductory items describing the respondent's profile (qualification, teaching level, schools, etc.); questions on lesson organisation and management in the classroom (methods used, content selection, spatial organisation, use of digital resources); items on perceived challenges and solutions, including safety measures and improvisation of materials; open-ended questions that allowed teachers to describe concrete practices, difficulties and examples of good management. The questionnaire was administered primarily via Google Forms, a free online platform accessible to all participants with a Google account, and was also available in printed form where needed. Approved informed consent was obtained from all subjects prior to participation, and all respondents participated voluntarily after being informed about the study objectives, procedures, and the confidential handling of their data.

Quantitative data were analysed in Microsoft Excel using frequencies and percentages. Open-ended responses were examined through thematic analysis to identify recurring themes (e.g., content selection, organisation, challenges, improvisation, and safety/hygiene measures). Together, these analyses described how teachers manage classroom-based physical education under spatial and organisational constraints.

RESULTS

The results are presented according to the sequence of questionnaire items, combining descriptive statistics with graphical representations to illustrate response distributions. The following subsections summarise the main findings regarding teachers' managing skills in teaching context, frequency of classroom-based instruction, preparation practices, instructional methods, curricular content and use of digital resources. The distribution of responses indicates that most teachers are required to conduct physical education lessons in the classroom with varying frequency. A total of six respondents (35.3%) reported that this occurs rarely, while four teachers (23.5%) indicated that they teach in the classroom often. Three respondents (17.6%) stated that this happens sometimes, whereas two teachers (11.8%) reported conducting such lessons very often. Only one teacher (5.9%) selected never, and another one (5.9%) stated very rarely (Figure 1).

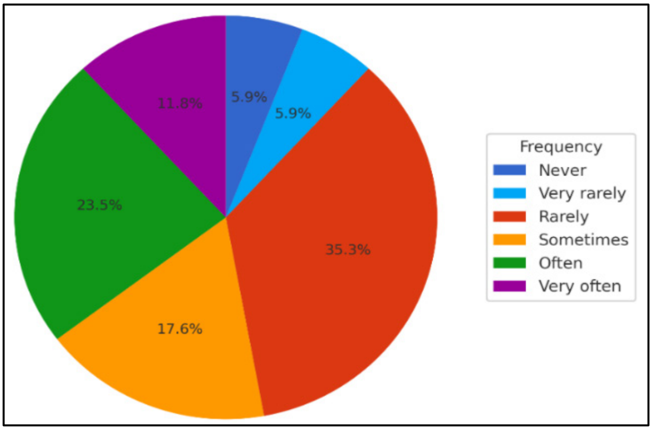

Fig. 1. Frequency of conducting PE lessons in the classroom

According to Table 1, only one teacher (5.9%) had attended training on conducting PE lessons in the classroom. Most respondents had not participated in such programmes, with six teachers (35.3%) selecting "No." Notably, nearly half of the participants (47.1%) expressed interest in attending such training, while two teachers (11.8%) did not consider it necessary.

Table 1. Participation in training sessions for conducting PE lessons in the classroom

Response option	Number of respondents	Percentage (%)
Yes	1	5.9%
No	6	35.3%
I would like to	8	47.1%
I do not consider it necessary	2	11.8%

According to Table 2, the most frequently reported preparation methods were adapting exercises (10 mentions) and reorganising classroom furniture (9 mentions). Fewer teachers indicated planning specifically for limited space (4 mentions), using available or improvised materials (3 mentions), or conducting theoretical activities (1 mention). Two respondents stated that they do not conduct PE lessons in the classroom. Regarding the class levels in which teachers conduct PE lessons in the classroom, most respondents reported working with primary classes (52.9%). Fewer teachers indicated teaching at the lower-secondary level (17.6%) or upper-secondary level (17.6%), while two respondents (11.8%) stated that they do not conduct classroom-based PE lessons.

Table 2. Preparation methods used by teachers for conducting PE lessons in the classroom

Preparation method	Number of mentions	Examples provided by respondents
Adapting exercises	10	*"I use exercises adapted to the space", "Static exercises"*
Moving/reorganising the furniture	9	*"I move the desks", "I ensure free space for activities", "Reorganising the furniture"*
Planning for limited space	4	*"I plan the lesson for reduced space", "Specific preparation"*
Using existing/improvised materials	3	*"I use what I have in the classroom", "Improvised materials"*
Theoretical activities	1	*"We discuss rules, competitions, projects"*
Does not conduct the lesson in the classroom	2	*"I do not teach in the classroom"*

The largest proportion of teachers (40%) reported that they need approximately 5 minutes to prepare the classroom space before a physical education lesson. Smaller groups indicated 1–2 minutes or 3–4 minutes (20% each), while 13.3% reported no preparation time at all. Only 6.7% stated that preparation requires 10 minutes (Figure 2). These findings indicate that most teachers perform quick spatial adjustments, with an estimated average preparation time of 4.1 minutes.

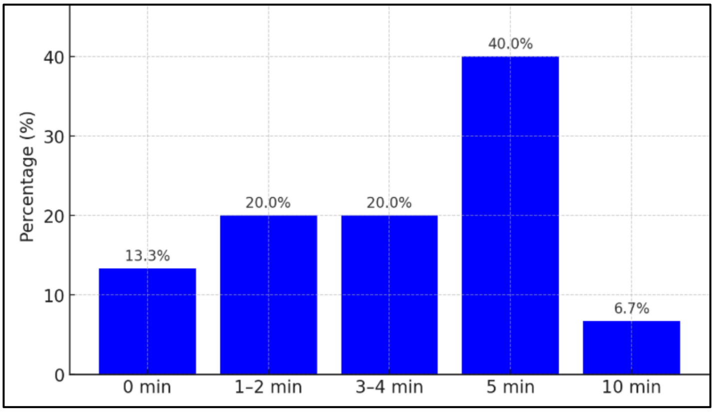

Fig. 2. Time allocated to organize the classroom to ensure space

The most frequently used strategy for adapting PE lessons to the classroom were low-intensity exercises (12 mentions, 70.6%), followed by alternative materials (10 mentions, 58.8%) and digital resources (8 mentions, 47.1%). Additional examples reported in the "Other" category included the use of video materials on game theory, rules, player positions, and the incorporation of activities such as learning chess (Figure 3).

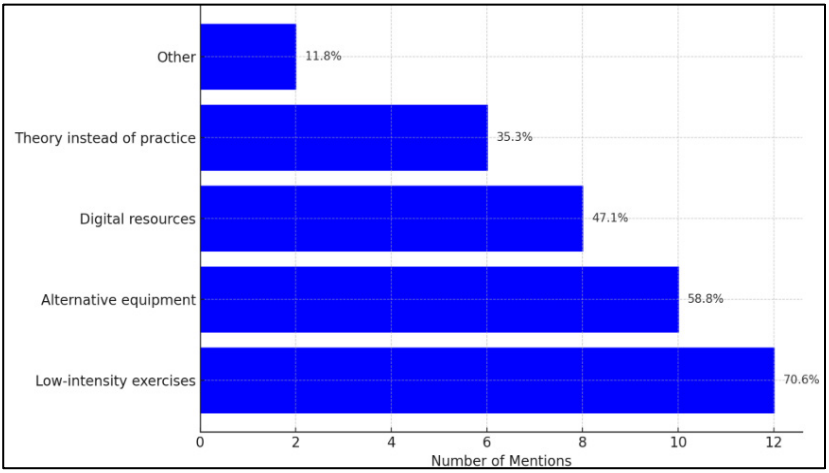

Fig. 3. Strategies used for adapting PE lessons

Distribution of curricular content most frequently used by teachers. The most prominent category is agility (coordination skills), selected by 14 teachers (82.4%). Strength and reaction speed follow with 10 mentions each (58.8%), reflecting an emphasis on low-space, individually executable motor skills. More spatially demanding components such as acrobatic gymnastic (35.3%) and aerobic gymnastic (23.5%) appear less frequently. The "Other" category (23.5%) includes dance, dexterity exercises, table tennis elements, dumbbell strength drills, and chess (Figure 4).

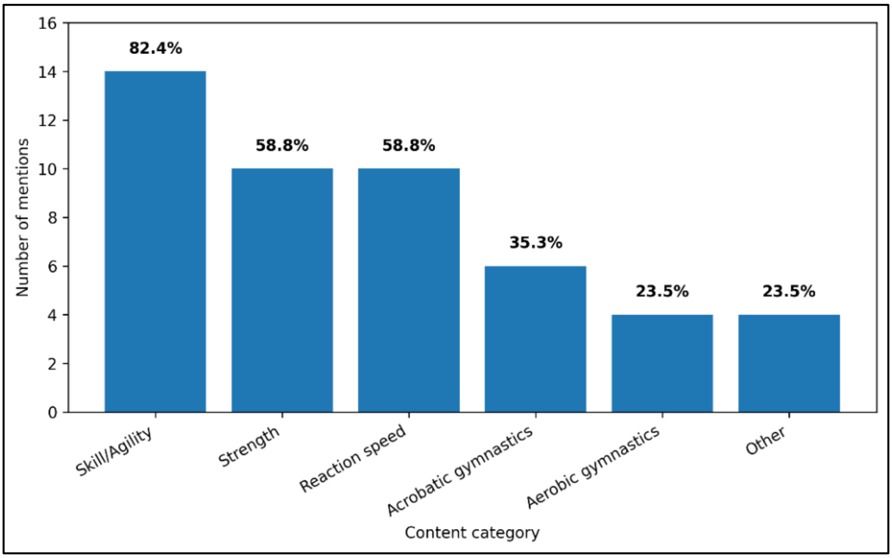

Fig. 4. Curricular content used in classroom-based PE lessons

Demonstrative videos (28.1%) and projectors (25.0%) emerged as the most commonly used digital resources in physical education lessons, indicating a preference for visual and easily accessible instructional tools. In contrast, smart boards were reported as the least frequently used resource (6.3%), suggesting limited availability or reduced applicability (Figure 5).

The most frequently applied hygiene measure is ventilation/aeration, reported by 52.9% of teachers (n=9). Respecting personal hygiene norms and having no specific hygiene measures appear equally common (35.3%, n=6 each). Fewer teachers reported equipment disinfection (17.6%, n=3), while only 5.9% (n=1) mentioned ensuring physical distancing or requiring handwashing at the end of the lesson (Figure 6).

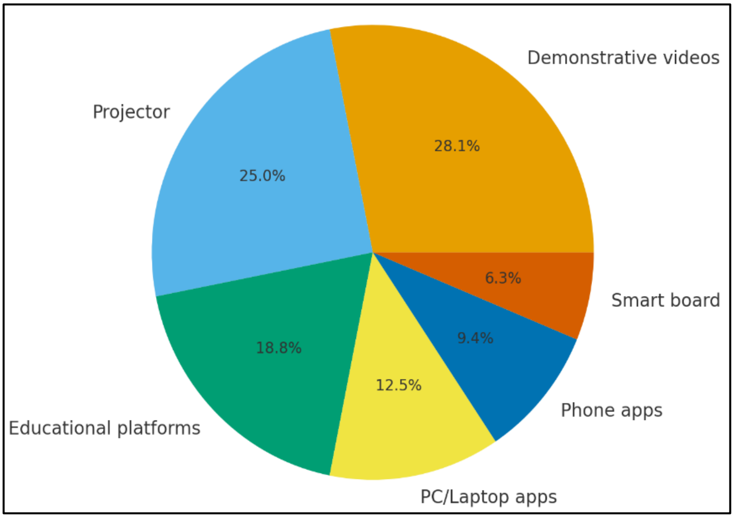

Fig. 5. Digital resources used in PE lessons

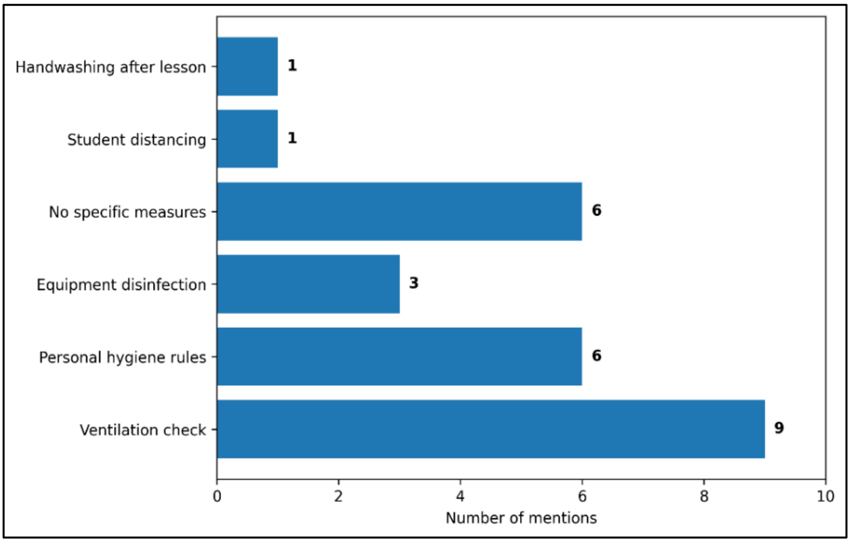

Fig. 6. Hygiene measures used in classroom-based PE lessons

The main obstacles identified by teachers when conducting physical education lessons in the classroom was space constraints, mentioned by 64.7% of respondents (n = 11). This is followed by the high number of students in the classroom (47.1%, n = 8) and the lack of equipment or materials (41.2%, n = 7).

A smaller proportion (23.5%, n = 4) reported other obstacles, such as limited furniture mobility, insufficient movement space, excessive noise, and a lack of material variety (Figure 7).

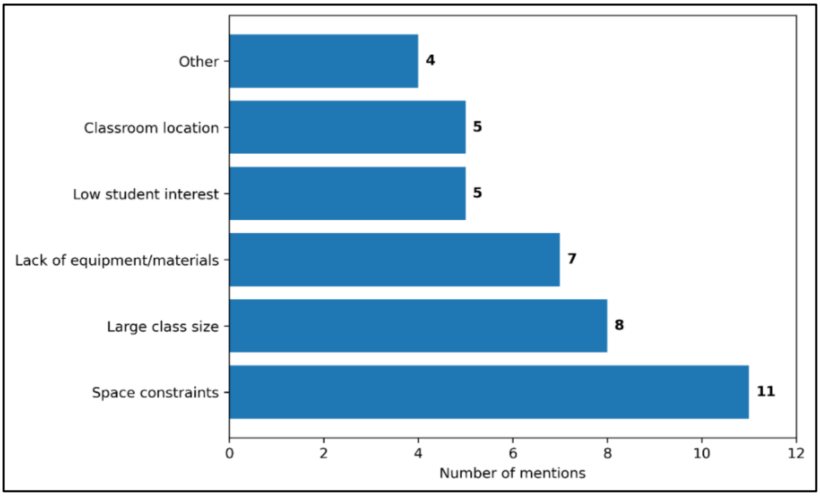

Fig. 7. Main obstacles identified in PE lessons conducted in classroom

DISCUSSIONS

The present study examined how teachers manage physical education lessons when they must be conducted in the classroom rather than in specialised sports facilities. This context introduces substantial pedagogical and organisational constraints, requiring teachers to make rapid decisions regarding safety, content selection, class management, and technological integration.

The findings reveal a highly adaptive teaching environment shaped by structural limitations, teacher competencies, and contextual demands.

A first notable result concerns the frequency and level at which classroom-based PE is practiced. More than half of the participating teachers (52.9%) reported delivering such lessons in primary school classes. This is consistent with broader evidence suggesting that environmental and infrastructural conditions strongly influence opportunities for physical activity and shape teaching patterns (Morton et al., 2016).

Younger pupils are more often assigned to indoor spaces due to weather, safety, scheduling, and facility constraints. Indoor lessons are common, professional preparation for teaching PE in limited classroom spaces is scarce. Findings from

Table 1 reveal that only one of the teachers involved in this study had received specialised training in this area, despite the fact that nearly half expressed interest in such professional development. This gap can be also found in previous studies emphasising the critical role of teacher competence in delivering high-quality PE instruction (Botgros & Franțuzan, 2010; Shandi et al., 2025). The absence of systematic training contributes to variability in the quality and safety of classroom-based lessons, as teachers rely predominantly on personal experience and improvisation.

Teachers' approach to organisation and space management further reflects these challenges. The chart regarding classroom preparation time (Fig. 2) indicates a mean of approximately 4.1 minutes needed to arrange a functional learning space. Most teachers required between three and five minutes to reorganise furniture, establish movement zones, or prepare materials. This fast turnaround underscores the need for efficient planning and aligns with Ghidarcea's (2012) findings that effective PE management in schools relies on the teacher's ability to optimise space and maintain clear organisational routines. The teaching strategies chosen by the respondents demonstrate a strong emphasis on control and safety (Fig. 3). These choices reflect established principles of classroom management, particularly when visibility is restricted and movement must be carefully monitored (Charette, 2018).

In terms of curricular content, teachers favoured activities that could be safely executed in limited space. The chart on content usage (Fig. 4) shows that coordination (82.4%), strength exercises (58.8%), and reaction speed tasks (58.8%) were the most frequently implemented. These motor skills require minimal displacement and allow for precise, controlled execution. Spatially demanding components, such as acrobatic and aerobic gymnastics, were used less often, reflecting the challenges of performing them safely in crowded classrooms. The prioritisation of low-intensity, skill-based activities mirrors patterns identified in previous research on physical activity in constrained environments (Blaes et al., 2013). A significant facilitator in this context is the use of digital tools, which play a major role in enhancing instruction when physical movement is restricted.

According to the digital-resources chart (Fig. 5), teachers most frequently employed demonstrative videos (64.3%), projectors (57.1%), and educational platforms (42.9%). These technologies support the visual demonstration of motor tasks, facilitate theoretical instruction, and help sustain student engagement. This aligns with contemporary research on blended learning in PE, which highlights the pedagogical value of digital integration (Manole, 2023; Țurcanu & Jurat, 2024). Furthermore, studies indicate that teacher support and clear instructional modelling (often enhanced through digital means) positively influence student engagement (Zhang et al., 2022; Guo et al., 2023).

However, despite the potential of digital resources, there are noteworthy inconsistencies in hygiene and safety measures. As shown in the hygiene chart (Fig. 6), the most common practices were ventilation checks (52.9%) and personal hygiene reminders (35.3%). Yet, more than one-third of the teachers (35.3%) reported not applying any specific hygiene measures during classroom-based lessons. Given the established importance of safety guidelines in PE settings, particularly indoors (Fitzgerald & Deutsch, 2016), this finding points to gaps in institutional support and the absence of standardised protocols for such learning environments.

Finally, the study identifies the structural challenges that most hinder effective classroom-based PE. The obstacle chart (Fig. 7), reflect systemic issues that limit the ability of teachers to deliver high-quality PE beyond the gymnasium. They also resonate with prior research demonstrating that limited facilities, inadequate equipment, and constraining spatial environments reduce student engagement and restrict the range of possible learning activities (Delidou et al., 2015; Morton et al., 2016). Teachers' qualitative comments reinforce these findings, noting challenges such as fixed classroom furniture, insufficient space for movement, excessive noise, and limited material variety.

Taken together, these results depict a PE instructional environment that relies heavily on teacher creativity, adaptability, and personal initiative. While teachers demonstrate resilience and resourcefulness, the broader structural and institutional conditions do not sufficiently support the delivery of safe, equitable and pedagogically coherent classroom-based PE.

CONCLUSIONS

This study showed that teaching physical education in the classroom has become a frequent necessity in many schools, especially at the primary level. Physical education teachers manage these lessons by adapting exercises and content, reorganising space, and integrating digital resources. However, the limited availability of formal training and the inconsistent application of hygiene and safety measures reveal a gap between curricular expectations and actual conditions. Persistent constraints, especially restricted space, large class sizes, and inadequate equipment indicate the need for clearer institutional guidance, targeted professional development, and improved infrastructural support to ensure safe and effective delivery.

AUTHORS CONTRIBUTION

Maria-Lorena Mogoș contributed to the conceptualization and design of the study, data collection, and initial drafting of the manuscript. Velu-Sebastian Bartha contributed to the methodological design, data analysis, interpretation of results. Remus Văidăhăzan contributed to the conceptualization and design of the study, the critical review of the methodology and discussion sections and provided scientific supervision and also manuscript revision. Ramona Ancuța Nuț contributed to data interpretation, scientific supervision and manuscript editing. All authors have read and agreed to the published version of the manuscript

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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EFFECTS OF A 12-WEEK VELOCITY-BASED TRAINING PROGRAM WITH LACTATE MONITORING ON 50 M FREESTYLE PERFORMANCE IN COMPETITIVE SWIMMERS

Dragoș NEAGU[1*], Simona PETRACOVSCHI[1]

ABSTRACT. *Introduction*: Training competitive swimmers involves the continuous development of general physical qualities and their subsequent application to specific performance. In sprint events, dry-land training plays a key role in developing strength and speed of execution. The objective monitoring of effort remains a significant challenge. *Objective*: This study aimed to determine the effects of implementing velocity-based training combined with swimming, alongside lactate level monitoring, to significantly improve performance compared to a traditional percentage-based programme. *Materials and methods*: Sixteen advanced swimmers, who were members of two university clubs, were divided into an experimental group and a control group. They followed a 12-week programme based on speed of execution and lactate analysis. Tests included the 50 m freestyle, determination of 1RM and speed of execution at 60% of 1RM. *Results*: Significant improvements were observed in the 50 m freestyle ($p = .03$; $d = 0.90$) and in the strength tests (1RM squat: $p = .018$; bench press: $p = .036$) in the experimental group. The control group showed minor changes, except for the bench press ($p < .001$). *Conclusions*: Speed training adjusted using lactate level testing improved performance and strength, demonstrating the effectiveness of objective monitoring and the customisation of tasks for athletes.

Keywords: fixed set velocity loss, resistance training, neuromuscular adaptation, metabolic adaptation, performance optimization

INTRODUCTION

One of the main problems faced by physical trainers is how to quantify and monitor athletes' training loads objectively in order to maximise performance. Several training variables have been identified in the design of physical training

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sessions, such as the type and order of exercises, intensity or load, number of repetitions and sets, and rest periods between sets (Bird et al., 2005; Kraemer and Ratamess, 2004). While most of these variables have received significant research attention, the possibility of manipulating the number of repetitions performed in each set relative to the maximum possible remains an unaddressed question in the literature (Sánchez-Medina and González-Badillo, 2011). Manipulating this variable determines the type of physiological responses and, ultimately, adaptations to strength training (Spiering et al., 2008). A reliable tool for assessing swimming-specific strength (both on land and in water) is evaluating strength-velocity exercises, which determine the relationship between weight lifted and speed (Gonjo et al., 2021).

Due to the limitations of percentage-based training (PBT), velocity-based training (VBT) has been suggested as a more effective way of prescribing training loads to improve general and specific performance (Włodarczyk et al., 2021; González-Badillo & Sánchez-Medina, 2010). VBT is superior to percentage-based training, particularly for elite athletes, as PBT has several limitations. Firstly, regular 1RM tests must be performed to prescribe the training load, which can lead to injury (Jovanovic and Flanagan, 2014; Włodarczyk et al., 2021). It is also impractical and time-consuming in large groups, and the values obtained contain a large margin of error (González-Badillo and Sánchez-Medina, 2010).

Secondly, changes in 1RM can occur after just a few training sessions and can fluctuate depending on physical condition, which can be caused by factors such as biological variability, training-related fatigue, lifestyle, sleep, stress and nutrition (González-Badillo and Sánchez-Medina, 2010; Jovanovic and Flanagan, 2014).

Velocity-based training approach is widely used by recreational athletes, but elite athletes use the aforementioned method differently (Hackett et al., 2018). This method enables daily readiness (or daily 1RM) to be estimated and allows speed decline within each set to be monitored in order to manage fatigue accumulation (González-Badillo and Sánchez-Medina, 2010; Jovanovic and Flanagan, 2014). Significant improvements in swimming performance have been achieved through low-volume, speed and strength training programmes when the selection of dry-land exercises is specific to the swimming event and muscle groups (Crowley et al., 2017; Crowley et al., 2018; Weston et al., 2015).

In VBT, two new variables are adopted for prescribing training load: the fastest initial repetition speed in sets is used to set the load instead of %1RM; and the velocity loss threshold (VLT) is used to finish the set instead of the traditional fixed number of repetitions. In a VBT approach, a working set is terminated if the mean concentric velocity (MV) of a repetition falls below a predetermined velocity loss threshold. The fixed set velocity loss (FSVL) method includes a predetermined training load and number of sets but not a prescribed number of repetitions (Banyard et al., 2018). For instance, Padulo et al. (2012) implemented a 20% velocity loss threshold and demonstrated that maintaining at least 80% of MV during training results in greater improvements in 1RM bench press compared to 1RM training alone (Padulo et al., 2012). Therefore, even if all participants perform the same number of repetitions per set with a given load during a training session, they may exert different levels of effort (Morán-Navarro et al., 2019; González-Badillo et al., 2017), since the number of repetitions remaining in each set can vary considerably between individuals. Instead of performing a fixed number of repetitions, it has been suggested that each training set should be stopped as soon as a predetermined magnitude or percentage of speed loss is reached (Morán-Navarro et al., 2019; González-Badillo et al., 2017; Rodríguez-Rosell et al., 2019).

Strong relationships have been observed between speed loss during weightlifting and metabolic measures of fatigue (Sánchez Medina & González-Badillo, 2011; Jovanovic & Flanagan, 2014). Research has shown that a high lactate concentration increases linearly during exercise as the number of repetitions performed in each set approaches the maximum (Sánchez Medina & González-Badillo, 2011; Gorostiaga et al., 2011). This leads to longer recovery times after training and a decrease in swimming-specific performance.

Due to the limited scientific evidence regarding the transfer of strength from land to water in swimmers, following the development of strength and speed on land, this study aims to analyse the assumption that integrating a speed-based strength development programme significantly improves performance in the 50 m freestyle event compared to the control group performing traditional strength training based on percentages. Training controlled by objective feedback also promotes significant neuromuscular adaptations.

MATERIAL AND METHODS

Study design

The present study was designed as a 12-week experimental intervention (divided into two phases: lactate training and power endurance training) aimed to compare the effects of two strength training methods on the performance of the 50 m freestyle (start from the water), with parallel groups. The study aimed to examine the effects of combining velocity-based training with swimming and adding lactate level monitoring to significantly improve performance compared to traditional percentage-based training (PBT).

Performance was evaluated using a series of tests conducted over the course of a week, with at least 24 hours' recovery time between sessions. The first testing session consisted of a swimming test, which was used as the main indicator of athletic performance. Maximum strength and execution speed were then assessed using the following methods: a) determining 1RM for squats; b) measuring execution speed at 60% of 1RM for squats; c) determining 1RM for bench press; d) measuring execution speed at 60% of 1RM for bench press.

Participants

Sixteen participants (five female and eleven male, aged 16.81 ± 2.28 years, with an average height of 174.44 ± 9.45 cm and an average weight of 65.81 ± 13.43 kg). All participants were advanced swimmers and members of two university clubs. Participants were selected based on their competitive experience and specific physical training to provide a clearer picture of the target population. The athletes were divided into two groups: an experimental group (n = 8) that performed a combined swimming and velocity-based strength training programme, and a control group (n = 8) that performed a combined swimming and percentage-based strength training programme. Parents or legal guardians of minors were required to give their consent for their children to participate in the study.

Procedure

The tests in this study were conducted under similar conditions for all participants at the same time in a controlled environment to minimise external factors. Participants were instructed to exert maximum effort during each test and to observe the recommended recovery period.

The main performance indicator is the 50 m freestyle test, which starts in the water. Prior to the test, all participants completed a standardised warm-up routine comprising 200 m crawl, 200 m medley and two 15 m sprints, to ensure neuromuscular activation. The test was conducted in two stages (pre- and post-test) with manual timing, and the total time was expressed in seconds. Maximum strength was determined for two fundamental exercises: squats and bench presses. This began with a progressive warm-up, after which the load increased from Olympic barbell lifts (without added weights) to 100–105% of the maximum, with a recovery period of 1–5 minutes between sets. The speed of execution was measured for the same exercises (squats and bench presses), with the concentric phase performed at maximum speed using a load equivalent to 60% of the previously determined 1RM. All participants underwent a specific warm-up and then performed two to three repetitions of the tested exercise.

The most common and accurate device used to measure speed during strength training is the linear position transducer (LPT). Typically, the LPT is connected to a display to provide real-time feedback on speed (Orange et al., 2020). Vitruve Fit is a linear position sensor device designed to transform the way athletes, coaches and health professionals measure and improve performance. Studies have shown these devices to have low measurement error and acceptable relative and absolute reliability (Hansen et al., 2011).

The Accutrend portable analyser was chosen for lactate level analysis because it is ranked among the most reliable and accurate field devices in the literature. Studies show that it correlates well with laboratory methods (Baldari et al., 2009; Stoll et al., 2018) and has low measurement variability. It also has the advantage of being highly practical and easy to use in a sports environment. Standard procedures were followed for the collection, management and analysis of blood lactate (Goodwin et al., 2007). Blood samples were collected from the earlobe before and after each experimental procedure.

Methods

The study intervention period lasted 12 weeks and involved three training sessions per week, supplemented by an additional mobility and flexibility session in some weeks. In addition to neuromuscular adaptations, metabolic components were integrated (lactacid training for the first seven weeks and power endurance training for the final five weeks), according to Signore (2021), to develop the anaerobic-lactic system, which is essential for sprint events.

There are three main functions of measuring lactate levels: a) validation, lactate levels can be used to confirm whether a session is lactacid or power endurance; b) adjustment, lactate levels can be used to adjust the speed loss threshold and breaks between sets. If the level is too low, breaks are reduced or volume is increased. If the level is high and speed decreases, volume is reduced or breaks are increased; c) prediction, very high lactate levels after a strength session may indicate reduced performance in swimming training.

Anaerobic lactate training (weeks 1–7) is a method that aims to improve tolerance to high blood lactate concentrations resulting from high-intensity exercise performed over short and medium durations. During training sessions, three to four sets of four to five exercises were performed, with each set lasting between 20 and 40 seconds and corresponding to approximately 10–15 repetitions. These were performed at 50–60% of 1RM with speed losses of ≤15% (0.75–1.3 m/s for the lower body and 0.60–0.80 m/s for the upper body). This speed loss threshold was determined following lactate testing one minute after the end of the set, when blood lactate concentrations are at their maximum. Test results showed values between 6 and 10 mmol/L (labelled 'lactate training' and correlated with speed loss), with higher concentrations recorded after lower body exercises. The breaks were short to medium in length to keep lactate levels high (1.5–3 minutes until the level drops to 5–7 mmol/L to maintain metabolic stress) and allow partial neuromuscular recovery.

During the second phase (weeks 8–12) of power endurance training, the intensity was reduced to 20–60% of 1RM. However, multiple sets (2–4) were performed with short breaks (30 seconds of work with a 15-second rest) between them, generating higher metabolic accumulations. The programme followed a wave-like pattern in terms of volume, ranging from two sets, four series and three exercises to three sets, four series and three exercises. Following metabolic testing, concentric speed was maintained at 0.75–1.3 m/s for the lower body and 0.60–0.80 m/s for the upper body, with a speed loss threshold of <10%. At this stage, lactate measurements were taken one to two minutes after completing a set and frequently showed values between 3 and 11 mmol/L. In some cases, when athletes intentionally exceeded the speed loss threshold, lactate levels rose above 11 mmol/L.

The most commonly used exercises during the intervention period were squats, bench presses, latissimus pulldowns, pullovers, medicine ball slams, deadlifts, plyometrics and plank variations.

Statistical analysis

Statistical analysis was performed using JASP v.0.19.3 software, which was chosen for its advanced functionality in reporting results according to APA format and for applying parametric and nonparametric tests. The level of statistical significance was set at $p < .05$ and normality of distribution was verified using the Shapiro–Wilk test supplemented by histogram analysis to avoid deviations from normal distribution. In all cases, the *p*-values were greater than 0.05, indicating a normal distribution and validating the application of parametric tests. Homogeneity between groups was verified using the Levene test, the results of which confirmed that the internal variability of the data was comparable between samples ($p \geq .05$). The results are presented as means ± standard deviation (M ± SD), including *t*-values, degrees of freedom (df), *p* and effect size (Cohen's d).

RESULTS

The Shapiro–Wilk normality test confirmed the normal distribution of the data ($W = 0.91$, $p = .36$), validating the application of the paired samples t-test.

Results from the 50 m freestyle test, performed with a start from the water, revealed differences between the experimental group (EG) and the control group (CG). In the EG, the average time decreased from 29.55 ± 4.52 seconds to 29.06 ± 4.03 seconds. This difference was statistically significant (p = 0.03, t(7) = 2.54) and had a large effect size (Cohen's d = 0.90). This improvement of approximately half a second confirms the effectiveness of the training programme based on speed monitoring and load control.

By contrast, the control group showed no significant changes in the 50 m freestyle test (with a start from the water), with an insignificant decrease from 28.11 ± 0.81 s to 28.02 ± 0.86 s (p = .46, t(7) = 0.76), indicating a small effect (Cohen's d = 0.27). These results demonstrate that traditional percentage-based training does not significantly improve sprint performance.

Table 1. Performance variables (50 m freestyle)

Variable	Pre (M ± SD)	Post (M ± SD)	*p* value	Effect size (Cohen's d)
Experimental Group (EG)				
50 m freestyle (s)	29.55 ± 4.52	29.06 ± 4.03	.03	0.90
Control Group (CG)				
50 m freestyle (s)	28.11 ± 0.81	28.02 ± 0.86	.46	0.27

Note. EG = Experimental Group; CG = Control Group. Significant differences at p < .05.

The results suggest that velocity-based training, adjusted according to monitored lactate levels, contributed to improved performance. Figure 1 shows the differences in performance before and after the experiment.

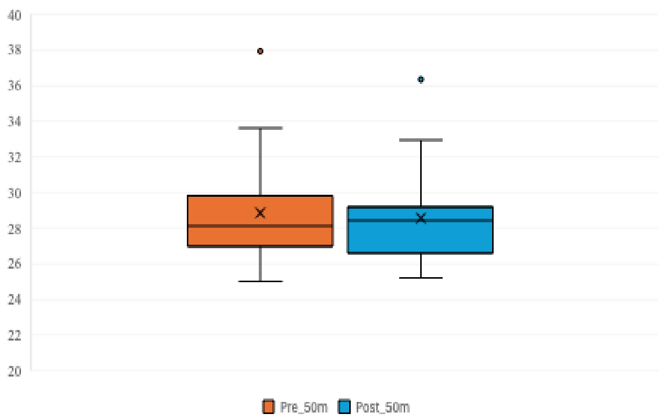

Fig. 1: Boxplot graphs for pre- and post-performance

For the 1RM squat test, athletes in the experimental group (EG) recorded a significant increase in performance, rising from an average of 106.56 ± 33.25 kg to 118.13 ± 31.05 kg (p = .018, t(7) = –3.09). This increase was considered to be of a large magnitude (d = 1.09), indicating clear neuromuscular adaptation.

In contrast, the control group showed a modest increase (from 81.00 ± 28.87 kg to 84.38 ± 27.30 kg), which was not statistically significant ($p = 0.089$, $d = 0.69$). Figure 2 shows the pre- and post-experiment differences.

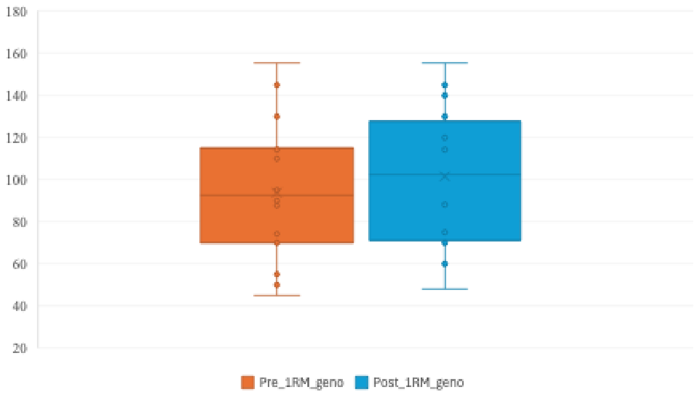

Fig. 2. Boxplot representation of 1RM in the bench press before and after genuflection

In the bench press, the experimental group (EG) progressed significantly from 82.19 ± 21.15 kg to 89.38 ± 27.80 kg ($p = .036$, $d = 0.91$), while the control group (CG) also achieved a significant increase, from 64.75 ± 22.47 kg to 69.94 ± 23.94 kg ($p < .001$, $d = 2.17$). However, the effect was influenced by the lower initial values and sample size. The differences before and after the experiment for the push are shown in Figure 3.

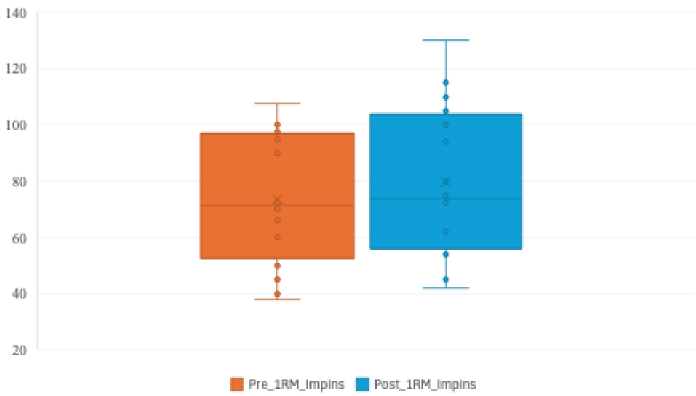

Fig. 3: Boxplot representation of 1RM in the push exercise, before and after.

In terms of speed execution at 60% of 1RM, the experimental group (EG) recorded a significant decrease in squats (from 0.74 ± 0.08 m/s to 0.68 ± 0.10 m/s, p = .011, d = 1.22), which suggests a possible adaptation towards maximum force production at the expense of execution speed. For bench press, however, the change was not significant (0.79 ± 0.22 m/s to 0.82 ± 0.18 m/s; p = 0.39; d = 0.32). In the control group, the results were significant for both the squat and the bench press.

Table 2. Strength and velocity variables (1RM and 60% velocity)

Variable	Pre (M ± SD)	Post (M ± SD)	*p* value	Effect size (Cohen's d)
Experimental Group (EG)				
1RM Squat (kg)	106.56 ± 33.25	118.13 ± 31.05	.018	1.09
1RM Bench Press (kg)	82.19 ± 21.15	89.38 ± 27.80	.036	0.91
Velocity Squat (m/s)	0.74 ± 0.08	0.68 ± 0.10	.011	1.22
Velocity Bench Press (m/s)	0.79 ± 0.22	0.82 ± 0.18	.39	0.32
Control Group (CG)				
1RM Squat (kg)	81.00 ± 28.87	84.38 ± 27.30	.089	0.69
1RM Bench Press (kg)	64.75 ± 22.47	69.94 ± 23.94	< .001	2.17
Velocity Squat (m/s)	0.75 ± 0.07	0.71 ± 0.09	.02	0.98
Velocity Bench Press (m/s)	0.86 ± 0.16	0.77 ± 0.12	< .001	1.95

Note. EG = Experimental Group; CG = Control Group. Significant differences at p < .05.

Overall, the speed-based training programme, which was adjusted using lactate level monitoring and the fixed set speed loss method, produced improvements in maximum strength (1RM). This supports the hypothesis that training controlled by objective feedback promotes significant neuromuscular adaptations, even though the speed at which submaximal tasks were executed did not change proportionally.

DISCUSSION

The main objective of this study was to investigate the effects of a velocity-based training programme (VBT) on performance in the 50 m freestyle (in water start) and on maximum strength (1RM), as well as on execution speed parameters at 60% of 1RM. All of these are associated with a physiological response. The results show that the experimental group experienced significant changes, confirming the initial hypotheses. In the 50 m freestyle with an underwater start, integrating a well-systematised velocity-based programme led to favourable neuromuscular and metabolic transfer. The athletes' neuromuscular capacity showed significant results in the maximum strength tests (1RM squat and 1RM bench press), confirming once again that the programme was successful. An interesting difference between the upper body and lower body was observed in the speed of execution at 60% of 1RM. Values for the bench press remained stable, suggesting that explosive capacity in the upper body was maintained. However, values for squats decreased slightly, possibly due to accumulated fatigue or specific adaptation to maximum strength.

The results obtained are in line with trends in the literature supporting the importance of physical training on land to improve aquatic performance. It was found that performing strength exercises with low to moderate loads and few repetitions per set at maximum execution speeds significantly improved various physical performance variables in elite junior swimmers (Marques et al., 2020). Several studies support the approach taken in this study, namely that high training volumes offer no immediate advantage over lower volumes (with higher intensity) in terms of swimming performance (Aspenes & Karlsen, 2012). Indeed, some studies have demonstrated moderate yet significant correlations between one-repetition maximum (1RM) bench press and short-distance swimming performance (15–50 m) in young competitive swimmers (Garrido et al., 2010). Conversely, testing and improving 1RM bench press and 1RM squat parameters explained 45–62% of the variation in swimming performance, providing further evidence of the importance of maximum strength for short-distance swimmers (Keiner et al., 2019).

The analysis also revealed some unexpected results. One of these was a 60% decrease in 1RM execution speed in the post-intervention tests, particularly for squats. While this decrease could initially be interpreted negatively, a closer look at the increase in maximum strength shows that heavier loads were used, which led to the decrease in speed. Recent research shows that execution speed and the performance level of athletes can affect the correlation with swimming speed (Tan et al., 2021). Furthermore, negative correlations between swimming speed and land-based strength have been observed due to the brief duration of the test (up to 30 seconds), indicating that longer tests may reveal a positive relationship between land-based strength and swimming speed (Morouço et al., 2011). Pareja-Blanco et al. (2016) also demonstrated that using a 20% speed loss threshold results in significant strength gains, in contrast to higher thresholds (e.g. 40%). Therefore, the choice of speed loss threshold should depend on the training objectives. In terms of practical application, the results of this study highlight that using a linear position transducer and lactate testing provides coaches with a complex tool for monitoring athletes' neuromuscular and metabolic responses, helping to prevent overload and optimise intensity. For instance, Wirtz et al. (2014) proposed that the relationship between exercise volume and lactate accumulation is non-linear. The finding that higher lactate levels were recorded during lower body exercises is consistent with previous research showing that larger muscle groups generate a more pronounced metabolic response (Beneke et al., 2002).

In practice, these methods can be applied to any sport in which rapid force production and fatigue control determine performance, such as athletics and cycling. Combining VBT with lactate monitoring can provide guidance for high-performance training, enabling recovery planning and the quantification of physiological stress.

However, there are a number of methodological and contextual limitations to the current intervention that must be acknowledged in order to better understand the scope of the conclusions. The sample size was relatively small (n = 16, eight in each group), which limits the generalisability of the results to larger groups of swimmers. A larger sample size would have enabled a more comprehensive statistical analysis and more effective control of variables such as age and experience. Another limitation is that strength and speed tests were performed on land while performance was tested in water, as environmental differences may influence the transfer of neuromuscular adaptations. Including tests performed in water (such as underwater traction force) would provide additional information on adaptation mechanisms. The lack of strict control over diet and sleep may have had a negative impact on lactate levels, neuromuscular recovery and daily physical fitness. Integrating a questionnaire for subjective monitoring of these variables could add validity to the study. However, the statistical significance identified ($p < .05$) and the consistency of the direction of change (increases in strength and decreases in 50 m times) support the validity of the conclusions.

For future research, it is recommended that the intervention is extended in order to analyse its long-term effects on neuromuscular and metabolic adaptations. In addition, a larger and more diverse sample should be included in terms of performance level and age. At the same time, lactate monitoring could be combined with other physiological indicators, such as heart rate, heart rate variability and sleep parameters, to improve our understanding of the adaptation process and other factors.

CONCLUSIONS

In conclusion, integrating a velocity-based training programme monitored by lactate level analysis has proven to be an effective strategy for improving swimming performance. This approach ensures strength development and maintains optimal load and recovery control. It also significantly transfers neuromuscular and metabolic adaptations to specific performance. This confirms the essential role of objective monitoring and individualisation in sports training.

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COMPETITIVE ANXIETY AMONG YOUNG SWIMMERS: THE ROLE OF PARENTAL INFLUENCE IN SHAPING ATHLETIC PERFORMANCE

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ABSTRACT. *Aim:* This study aims to assess the level of anxiety young swimmers experience in a competition and to identify differences between perceived and desired parental behaviours in relation to athletic performance. *Methods:* 16 boys and girls, aged 12.06 ± 2.01 on average, were included in this study with their parents' consent. All participants filled in the Competitive State Anxiety Inventory—2 (CSAI-2; Martens et al., 1983) and the Parental Involvement in Sport Questionnaire (PISQ) created by Lee and MacLean, 1997). Statistical processing was performed using SPSS (version 19). The t-test for paired samples was used to compare the results in terms of perceived and desired parental behaviour in relation to young swimmers' performance. The significance threshold applied in this study was $p \leq 0.05$. *Results:* Young swimmers have increased confidence in their own abilities (M = 17.25, SD = 2.49). The total anxiety score (M = 33.50, SD = 4.66) shows that young swimmers are quite concerned about competition. The data show that there is no statistically significant difference between genders in terms of total anxiety score (χ^2= 17.92, df = 20, p = 0.59). According to the statistical analysis, the average scores of perceived and desired mother behaviour differ significantly (M = 4.81, t = 5.4, df = 15, p < 0.001). The difference between perceived and desired father behaviour in relation to competition is not statistically significant (M = 0.68, t = 0.6, df =15, p = 0.55). There is a statistically significant difference between the average scores of perceived mother and father behaviour (M = 6.87, t = 4.74, df =15, p < 0.001). There is a statistically significant difference between perceived pressure and desired parental behaviour (M = 6.12, t = 4.21, df =15, p = 0.001). *Conclusions:* Children show confidence in their own abilities before competition (M = 17.25). There is no statistically significant difference between girls and boys in terms of total anxiety score. Both parents are involved in supporting athletes, with the father being deemed to be the one

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who puts more pressure on children. Children state that they would like their mothers to be more concerned with their results, which would give them support and encouragement. Swimmers at this age feel pressure but would like their parents to be even more involved in supporting them when it comes to participating in competitions.

Keywords: swimming; anxiety; perception; desire; behaviour.

INTRODUCTION

Those who have practiced high-performance sports know how important it is for athletes to be able to control their emotions before, during, and after a competition. Emotional instability contributes to technical errors, which will impact the results of a competition. Prolonged high levels of anxiety in children lead to cognitive problems that can affect their adult lives (Arantes de Araújo et al., 2020). But at the same time, in the absence of a certain degree of anxiety, people would not be as motivated to study or work responsibly (Feldman, 2011).

Parents offer emotional and financial support to ensure that they children will be involved in sport activities (Wolfenden & Holt, 2005; Holt & Knight, 2014; Gao et al., 2024). When it comes to sports, parents are the ones who bring their children into the sporting environment, and they are also the ones who will provide them with material and emotional support throughout their careers (Fredricks & Eccles, 2005; Bonavolontà et al., 2021). Parents play an important role in athletic performance, influencing their children's emotional states, both satisfaction and anxiety (Holt et al., 2008; Baciu et al., 2015). This study aims to assess the level of anxiety young swimmers experience in competition and to identify differences between perceived and desired parental behaviours in relation to athletic performance.

MATERIAL AND METHODS

16 boys and girls, aged 12.06 ± 2.01 on average, participated in this study.

We used two questionnaires to collect data. The first one is Competitive State Anxiety Inventory—2 (CSAI-2) (Martens et al., 1983), which uses a 1 to 4 Likert scale - 1: Not at all; 4: Very much so; this questionnaire helped us get scores on cognitive state anxiety, somatic state anxiety, and self-confidence. The second questionnaire is Parental Involvement in Sport Questionnaire (PISQ), which uses a 1 to 5 Likert scale - 1: Always; 5: Never.

The data were collected from 16 children before their participation in an official swimming competition. The children were assisted by their parents in filling in the questionnaires.

RESULTS

Cognitive anxiety, related to thoughts about performance, has an average score of (M = 6.75, SD = 2.24), which indicates that concerns about performance are moderate. Somatic anxiety, characterized by physiological changes, has an average score of (M = 9.13, SD = 3.16), which indicates significant physiological changes before competition. Confidence level has an average score of (M = 17.25, SD = 2.49), which shows that young swimmers have increased confidence in their own abilities around competition time. The total anxiety score is quite high; the mean anxiety score of (M = 33.50, SD = 4.66) shows young swimmers' concern about the competition. (Table 1).

Table 1. Anxiety scores

	N	Minimum	Maximum	Mean	Std. Deviation
Total anxiety score	16	23	41	33.50	4.662
Cognitive Anxiety	16	4	10	6.75	2.236
Somatic Anxiety	16	5	16	9.13	3.160
Confidence	16	12	20	17.25	2.490
Valid N (listwise)	16				

The Likert scale that we used in our study ranges from 1 to 5 - 1: Always; 5: Never. As one can see, the average score of desired mother behaviour (M = 30.12, SD = 6.55) is lower than the average score of perceived mother involvement (M = 34.93, SD = 6.43) (Table 2). This shows that young athletes would like their mothers to be more involved in their performance in competition, which would provide them with support and encouragement.

Table 2. Perceived mother involvement and desired mother behaviour scores

	Mean	N	Std. Deviation	Std. Error Mean
Perceived mother involvement	34.9375	16	6.43396	1.60849
Desired mother behaviour	30.1250	16	6.55108	1.63777

Child swimmers would like their mothers to be more involved in their participation in competitions. According to the statistical analysis, the perceived involvement scores and the desired involvement scores differ significantly. (M = 4.81, t = 5.4, df =15, p < 0.001) (Table 3).

Table 3. Difference between perceived mother involvement and desired mother involvement average scores

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Perceived mother involvement Desired mother behaviour	4.81250	3.56312	.89078	5.403	15	.000

There is a subtle difference between children's perceived father behaviour (M = 28.06, SD = 7.37) and desired father behaviour (M = 27.37, SD = 5.69) in relation to participation in competitions. Both means are below the average score of desired mother involvement, which shows that athletes chose low values on the Likert scale - 1: always, 2: quite often (Table 4).

Table 4. Perceived/desired father involvement scores

	Mean	N	Std. Deviation	Std. Error Mean
Perceived father involvement	28.0625	16	7.37987	1.84497
Desired father behaviour	27.3750	16	5.69064	1.42266

The similar scores of perceived father involvement and desired father behaviour show that fathers are involved in supporting their children to achieve sport performance. The difference between perceived and desired behaviour is not significant (M = 0.68, t = 0.6, df =15, p = 0.55) (Table 5).

Table 5. Difference between perceived father involvement and desired father involvement average scores

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Perceived father involvement Desired father behaviour	.68750	4.54193	1.13548	.605	15	.554

If we compare the average scores of perceived mother behaviour (M = 34.93, SD = 6.43) and perceived father behaviour (M = 28.06, SD = 7.37), we notice that fathers are perceived as being more involved in relation to their children's participation in a competition (Table 6).

Table 6. Perceived mother/father involvement scores

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Perceived mother involvement	34.9375	16	6.43396	1.60849
Perceived father involvement	28.0625	16	7.37987	1.84497

As regards parental involvement, fathers are perceived as being more concerned with their children's competition results. There is a statistically significant difference between the average score of perceived mother involvement and that of perceived father involvement (M = 6.87, t = 4.74, df =15, $p < 0.001$) (Table 7).

Table 7. Difference between perceived mother involvement and perceived father involvement average scores

	Mean	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed)**
Perceived mother involvement Perceived father involvement	6.87500	5.79511	1.44878	4.745	15	.000

There is a difference between children's perceived pressure on them (M = 63.62, SD = 12.97) and how they would like this pressure to be (M = 57.50, SD = 11.89) around a competition.

The Likert scale - 1: always, 2: quite often, 5: never - and the fact that the average score of desired behaviour is lower than that of perceived behaviour reveal that child athletes would like more involvement from their parents (Table 8).

Table 8. Perceived and desired pressure scores

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Perceived pressure	63.6250	16	12.97626	3.24407
Desired pressure	57.5000	16	11.89398	2.97349

According to our data, children feel pressure from their parents but would like them to be even more involved in supporting them when it comes to participating in competitions. There is a statistically significant difference between perceived pressure and desired parental behaviour (M = 6.12, t = 4.21, df =15, p = 0.001) (Table 9).

Table 9. Difference between perceived involvement and desired involvement average scores

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Perceived pressure – Desired pressure	6.12500	5.81808	1.45452	4.211	15	.001

We wanted to find out if there was a significant difference between boys and girls in terms of perceived parental pressure, but no significant differences were found. An almost significant difference was found in perceived mother pressure, as girls reported higher scores than boys (χ^2= 29.78, df = 20, p = 0.07). (Table 10).

Table 10. Chi Square test: gender and perceived mother behaviour

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29.778[a]	20	.074
Likelihood Ratio	24.899	20	.205
Linear-by-Linear Association	.673	1	.412
N of Valid Cases	16		

The data show that there is no statistically significant difference between boys and girls in terms of total anxiety score (χ^2= 17.92, df = 20, p = 0.59). (Table 11).

Table 11. Chi Square test: gender and total anxiety score

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.926[a]	20	.592
Likelihood Ratio	18.307	20	.567
Linear-by-Linear Association	.764	1	.382
N of Valid Cases	16		

DISCUSSION

A series of studies show that, as a rule, children appreciate their parents' interest in offering them sports activities, as long as their interventions provide a positive emotional environment (Anderson et al., 2003; Wilson & Spink, 2011; Bonavolontà et al., 2021).

A study involving children participating in a tennis competition reveals that girls perceive a higher level of pressure from their parents than boys (Bois et al., 2009). In our study, data analysis shows that there is no statistically significant difference in terms of gender and total anxiety score. There is also no significant difference in terms of gender and perceived parental pressure.

According to one study, the presence of one or both parents influences the degree of anxiety differently. The presence of both parents is associated with a high level of pre-competition anxiety, especially among girls participating in a tennis competition (Bois et al., 2009).

In a competition, young wrestlers showed joy due to the positive involvement of their parents and their satisfaction with their children's activity (Scanlan & Lewthwaite, 1986; Holt et al., 2008).

In our study, both parents were present at the competition, and the data show that swimmers would like their mothers to be more involved in emotionally supporting their participation in the competition.

As for fathers, it appears that they are more involved than mothers in supporting their children's participation in competitions, and there is no statistically significant difference between perceived and desired father behaviour.

In a study involving 37 swimmers aged 12.22 on average, more than half of them state that they were supported by both parents, one third perceived their mother's support as more relevant, while 10% perceived their father's support as more relevant (F. Javier Ponseti et al., 2016).

Data from another study show that swimmers perceive more pressure than they would like (Dasinger, 2014). Another study we consulted states that excessive parental involvement creates an additional source of pressure, and that children would prefer this involvement to take the form of encouragement, praise, and understanding (Mastrorilli & Greco, 2020). Children's perception that their parents are overly involved is associated with burnout and increased anxiety (Gould et al., 1996; Leff & Hoyle, 1995; Holt et al., 2008).

In our study, children feel some pressure from their parents but would like them to be even more involved in supporting them when it comes to participating in competitions.

CONCLUSIONS

Our study data reveal that although the level of anxiety is quite high (M = 33.50), children show confidence in their own abilities before the competition (M = 17.25). There is no statistically significant difference between girls and boys in terms of total anxiety scores (χ^2= 17.92, df = 20, p = 0.59).

No statistically significant differences are found between children's gender and their perceived parental pressure.

Both parents are involved in supporting athletes, with the father being considered to be the one who puts more pressure on children. As regards the perceived level of involvement of the two parents, the difference is statistically significant, with the father being more involved.

As for mother behaviour, children state that they would like their mothers to be more concerned with their results, which would provide them with support and encouragement.

The child swimmers in this study feel pressure but would like their parents to be even more involved in supporting and encouraging them when it comes to participating in competitions.

There is a statistically significant difference between perceived parental pressure and desired parental behaviour.

It is important for parents to exert some pressure on their children in sports competitions, but to try and make this pressure beneficial, in the form of praise and encouragement, thus increasing their children's chances of achieving high results and, at the same time, creating a healthy environment for young athletes' mental and emotional development.

AUTHOR CONTRIBUTIONS
All the authors contributed equally to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST
There are no conflicts of interest to declare concerning this study.

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A HOLISTIC–ECOLOGICAL PERSPECTIVE ON THE JUNIOR-TO-SENIOR TRANSITION IN FOOTBALL

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ABSTRACT. *Introduction:* The transition from youth to senior football represents a complex process of psychological, social, and performance adaptation. A holistic–ecological approach emphasizes that this passage depends not only on technical readiness but also on motivational and self-regulatory development. *Objective:* This study aimed to evaluate the impact of the Personal Development Plan (PDP) and Personal Action Plan (PAP) on the psychological readiness, motivation, and self-efficacy of a youth player transitioning to senior football within FC Universitatea Cluj Academy. *Material and Methods:* A single-case longitudinal design was applied during the 2024–2025 season with a 17-year-old left winger. The intervention combined individualized PDP and PAP implementation with three assessment stages using the Sport Motivation Scale II (SMS-II), Athlete Self-Efficacy Scale (ASES), monthly reflection logs, and coach evaluations. Quantitative data were analyzed descriptively, while qualitative reflections were interpreted thematically. *Results:* The findings showed consistent growth in intrinsic motivation, integrated regulation, and all four dimensions of self-efficacy. Reflection logs and coach reports confirmed improvements in emotional control, communication, and self-regulated learning. By the end of the monitored season, the athlete achieved professional readiness and made his official debut in Romania's top division (Liga I) in September 2025. *Discussion:* The results confirm that structured PDP and PAP frameworks, supported by reflective practice and psychological monitoring, enhance athletes' motivation, confidence, and adaptability during transition. *Conclusions:* The study highlights the effectiveness of holistic, individualized development planning in facilitating sustainable progression from youth to senior football.

Keywords: Career transition; personal development plan; personal action plan; youth football.

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INTRODUCTION

Athletic career transitions are increasingly recognized as complex, multidimensional, and interactive processes rather than isolated events (Stambulova & Wylleman, 2019; Wylleman, Reints, & De Knop, 2013). Moving from one stage of sport participation to another—most notably from youth to senior competition—requires not only technical and tactical readiness but also psychological, social, and educational adaptation. The theoretical evolution of this field has shifted from linear, stage-based models toward holistic and ecological frameworks that capture the interdependence between the individual and their environment (Henriksen et al., 2020).

A holistic perspective emphasizes the need to view the athlete as a complete person, whose development occurs simultaneously across athletic, psychological, psychosocial, academic, and vocational domains (Wylleman et al., 2013). Successful transitions require synchronization among these life spheres, as well as the capacity to maintain emotional equilibrium and motivation under new performance demands. Such balance is central to theories of self-regulation, autonomy, and environmental fit, which posit that adaptive functioning depends on both individual agency and the quality of contextual support (Stambulova & Wylleman, 2019).

Interventions grounded in this framework advocate individualized, context-sensitive approaches that combine personal reflection with systemic support (Henriksen et al., 2020). Structured tools such as *Personal Development Plans* (PDPs) and *Personal Action Plans* (PAPs) operationalize this theory by transforming abstract developmental goals into measurable, actionable strategies (Stambulova & Wylleman, 2019). These instruments encourage autonomy, enhance self-awareness, and ensure that sport-specific growth occurs in concert with psychological and educational development.

Ultimately, the holistic–ecological model reframes career transition as an integral component of the athlete's life trajectory—a process of reciprocal adaptation between person and environment, demanding both internal resilience and external support. By embedding transition management within the broader ecosystem of sport and education, this paradigm promotes not only high performance but also well-being, identity continuity, and sustainable personal growth (Wylleman et al., 2013; Stambulova et al., 2020).

PDP and PAP as Planning Tools in Athlete Development

A PDP is typically defined as a structured and individualized document that helps athletes identify personal goals, assess current competencies, and plan strategies for continuous development (Morris & Cartigny, 2020). Within sport contexts, PDPs guide athletes to articulate their aspirations across both performance and non-performance domains, linking skill enhancement with psychological and educational growth (Wylleman & Lavallee, 2004). By facilitating ongoing self-assessment and dialogue between the athlete, coach, and support staff, PDPs promote self-awareness, autonomy, and intrinsic motivation, all of which are essential for long-term success (Deci & Ryan, 2000).

A major strength of PDPs lies in their emphasis on active engagement and self-assessment. They encourage athletes to assume ownership of their developmental trajectory by setting realistic performance, educational, and psychosocial goals. This aligns with contemporary transition theories, which position the athlete not as a passive recipient of support but as an active manager of their career pathway (Stambulova, 2009; Wylleman, Reints, & De Knop, 2013). Moreover, the reflective component of PDPs promotes awareness of emotional states and facilitates early identification of stress or maladaptive coping, which are among the most significant predictors of poor mental health during transitions (Henriksen et al., 2020).

PAPs complement this approach by focusing on actionable steps and measurable outcomes. While PDPs define long-term developmental goals, PAPs emphasize implementation—translating strategy into structured activities supported by coaches, sport psychologists, and educators. This interaction between planning and execution creates a feedback loop in which progress is continuously monitored, and interventions are adjusted according to situational challenges. In doing so, PAPs reinforce the ecological notion that athlete development is contingent upon both personal and contextual alignment (Stambulova, Ryba, & Henriksen, 2020).

Complementing this, the PAP serves as the implementation mechanism of the PDP. While the PDP establishes direction and developmental objectives, the PAP translates them into concrete, measurable actions, defining specific tasks, timelines, and criteria for evaluation (Rumbold et al., 2012). The PAP therefore represents the bridge between intention and execution—transforming reflection into systematic practice through ongoing feedback and monitoring.

Evidence from recent systematic reviews highlights that effective transition management requires goal-oriented, self-reflective frameworks that help athletes articulate short- and long-term objectives, identify resources and barriers, and implement adaptive coping strategies (McCluskey, Stevens, Cruwys, Murray, & Freeman, 2025). Planning instruments such as PDPs and PAPs operationalize these principles by creating individualized roadmaps that combine personal agency with structured mentorship. Through periodic review and adaptation, these plans foster self-regulation, resilience, and accountability—key factors associated with psychological well-being during periods of change.

Psychological Resources & Well-Being in Transition

Athletic transitions represent periods of heightened vulnerability but also of potential growth, where psychological resources play a decisive role in determining adaptation and well-being. The transition from youth to senior sport—often accompanied by increased expectations, performance pressure, and social redefinition—demands more than physical readiness. It requires emotional regulation, coping flexibility, self-efficacy, and resilience, which together form the psychological foundation for sustained engagement and optimal functioning (Stambulova, 2009; Galli & Vealey, 2008).

Recent qualitative findings from Norwegian football academies highlight that psychological well-being in transition is profoundly shaped by social and relational processes, particularly by parental involvement and support (Ohla, Erikstad, & Sæther, 2025). In these contexts, emotional security and perceived social connectedness act as protective psychological resources, buffering athletes against the pressures of adapting to new environments and performance demands.

The study found that the transition from youth to professional academy football involves not only heightened athletic expectations but also significant changes in identity and belonging. Athletes reported that entering a professional structure meant redefining themselves from being standout players at their local clubs to becoming "one among many" in a highly competitive environment—a shift requiring substantial emotional adjustment and self-regulation. Psychological resources such as confidence, motivation, and adaptability were critical for coping with this transition phase (Drew, Morris, Tod, & Eubank, 2019; Ohla et al., 2025).

These findings reaffirm that well-being during transition extends beyond individual traits to encompass socially embedded psychological resources—including supportive communication, reflective dialogue, and a sense of belonging within both family and sport environments. Complementing this, Gherman et al. (2021) underline that sustained physical activity is inseparable from psychological balance, reinforcing the ecological view that development extends beyond physical readiness to encompass self-regulation and mental well-being.

The Role of the Coach and the Support Environment

The transition from youth to senior football is a multifaceted developmental challenge that depends as much on contextual support as on individual competencies. Within the holistic–ecological paradigm, the coach and the support environment are considered central agents in shaping how athletes perceive, interpret, and respond to transitional demands (Henriksen, Stambulova, & Roessler, 2010; Stambulova, Ryba, & Henriksen, 2020). Coaches not only direct athletic performance but also function as social and psychological architects, influencing athletes' motivation, confidence, and sense of belonging (Jowett & Cockerill, 2003).

Empirical findings show that the coach–athlete relationship quality directly predicts the degree of psychological safety within teams. Şenel et al. (2024) demonstrated that athletes' perceptions of autonomy-supportive behaviors were strongly associated with their ability to communicate errors, ask questions, and take interpersonal risks—factors essential for learning and confidence-building during transitions. Similarly, Hurst and Kavussanu (2025) found that authentic leadership behaviors in coaches—such as transparency, consistency, and relational trust—positively influence athlete well-being through the mediating role of psychological safety, whereas interpersonal hostility erodes this mechanism.

Qualitative investigations further caution that psychological safety in elite sport is context-dependent rather than uniform. Athletes often distinguish between feeling safe to experiment on the field and safe to speak off the field, suggesting that situational sensitivity is vital in coaching practice (Ulster University, 2024). Coaches who explicitly normalize mistakes as learning opportunities and separate "challenge to improve" from "threat to self-worth" create developmental spaces where players feel both stretched and supported. This is particularly crucial in junior-to-senior transitions, where risk-taking and accelerated learning coexist with heightened scrutiny and social comparison.

Ultimately, the role of the coach and support environment extends beyond technical instruction—it involves the intentional design of relational and organizational conditions that promote trust, openness, and shared purpose. When athletes experience a climate of respect, constructive feedback, and emotional safety, transitions cease to be moments of rupture and instead become catalysts for growth, resilience, and identity consolidation.

MATERIAL AND METHODS

This study employed a single-case qualitative design to explore the impact of individualized development tools —PDP and PAP— on the transition process from youth to senior football. The research was conducted within the professional environment of FC Universitatea Cluj, a club competing in Romania's top football division, Liga 1.

The investigation took place over the 2024–2025 competitive season, during which the participant, an elite youth player, engaged in a structured, year-long development program guided by the club's technical and psychological staff.

Participant

FC Universitatea Cluj Academy was chosen as the research setting due to its recognized status among the top academies in Romania, its consistent national performance, and its holistic athlete development model supported by full multidisciplinary staff across all elite age categories.

The study involved a single male participant, aged 17 at the beginning of the 2024–2025 season, playing as a left winger for FC Universitatea Cluj Academy. He was selected at the recommendation of the academy's technical and psychological staff, based on his talent, training discipline, competitive performances, and results in internal testing. The left winger position demands exceptional speed, agility, tactical intelligence, and creativity—skills that, at this developmental stage, are closely associated with decision-making maturity and readiness for senior-level football.

Prior to the study, the athlete, his parents, and the club administration were fully informed about the research objectives and ethical standards. All parties provided written consent for participation and for the use of anonymized data under the athlete's initials (M.O.).

Procedure

The data collected throughout the 2024–2025 competitive season were analyzed using a mixed-methods approach, combining descriptive statistics with qualitative thematic interpretation. This design enabled a comprehensive understanding of the player's psychological and motivational evolution during his transition from youth to senior football.

The quantitative and qualitative analyses were guided by the individualized objectives established in the athlete's PDP and PAP. The PDP outlined four key domains of improvement:

- *Technical–tactical*: enhancing 1v1 offensive duels, crossing precision, and decision-making in the final third.
- *Physical:* increasing anaerobic endurance and repeated sprint ability, particularly in transition phases.
- *Psychological:* strengthening self-confidence, emotional regulation during high-pressure moments, and maintaining focus after errors.
- *Social and professional*: improving communication with senior teammates and demonstrating proactive behavior in training sessions.

Each objective in the PDP was accompanied by measurable indicators — for example, technical execution rate (successful crosses, dribbles completed), subjective confidence levels reported in the reflection log, and observational ratings from the coaching staff.

The PAP operationalized these objectives into monthly micro-goals and behavioral commitments. For instance, under the psychological domain, the player committed to maintaining a post-training reflection journal, setting one self-efficacy goal per week, and reviewing progress biweekly with the psychologist. In the tactical domain, he set goals such as improving off-ball positioning and synchronization with the left-back in both offensive and defensive phases.

Both plans were dynamic documents, reviewed every six weeks to ensure responsiveness to the athlete's evolution and feedback from coaches. Adjustments were made as the player began training more frequently with the senior team, shifting emphasis from technical refinement to emotional regulation and social adaptation within the professional environment.

Quantitative analysis

The quantitative data derived from the *Sport Motivation Scale II* (SMS-II; Pelletier et al., 2013) and the *Athlete Self-Efficacy Scale* (ASES; Moritz et al., 2000) were examined at three assessment points: T1 (Pre-season, July 2024); T2 (Mid-season, January 2025); T3 (Post-season, June 2025).

Both questionnaires were administered in English, as the participant demonstrated adequate language proficiency. Prior to the first administration, the club's sport psychologist conducted a brief conversation in English to confirm comprehension. The tests were completed individually, in paper-based format, in a quiet office environment at the club's facilities.

Descriptive statistics (means and percentage variations) were calculated to evaluate longitudinal changes between the three time points. Comparative visualizations (line and radar charts) were produced to illustrate the direction and magnitude of motivational and self-efficacy growth across the competitive cycle.

Qualitative analysis

Qualitative data were obtained from two complementary instruments: the Athlete Reflection Log and the Coach Evaluation Form, both completed monthly during the season. The reflection logs were analyzed using a thematic content approach, identifying recurrent themes such as self-confidence, emotional control, adaptability, and learning mindset. The coach's evaluations were cross-referenced with the athlete's reflections to ensure consistency and contextual depth, highlighting observable behavioral changes and professional integration.

To enhance validity and interpretive richness, a triangulation strategy was applied, integrating quantitative and qualitative results. The temporal alignment between improvements in motivational and self-efficacy scores (SMS-II and ASES) and corresponding qualitative indicators (e.g., increased confidence, initiative, and resilience) allowed for a holistic interpretation of the athlete's developmental trajectory. This multi-layered analysis aimed to capture not only performance-related progress but also psychosocial adaptation and psychological well-being throughout the transition period.

Materials

PDP served as the central framework for setting long-term objectives across four dimensions: technical–tactical improvement, physical conditioning, psychological skills, and social integration.

PAP operationalized these objectives through monthly measurable actions and behavioral indicators, allowing for the continuous monitoring of progress. Both instruments were co-constructed by the player, coach, and sport director to ensure alignment between individual and team development goals.

To quantitatively assess motivational and psychological changes over time, two standardized instruments were used: SMS-II and ASES. The SMS-II measures six motivational subdimensions — intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation — using 18 items rated on a 7-point Likert scale (1 = does not correspond at all, 7 = corresponds exactly). The ASES comprises 13 items assessing situational confidence across technical, tactical, physical, and mental domains, using a similar 7-point scale (1 = not at all confident, 7 = completely confident). Both instruments demonstrate high internal consistency ($\alpha > .80$) and have been validated in cross-cultural sport research.

Complementary qualitative data were gathered through the Athlete Reflection Log and the Coach Evaluation Form, both completed monthly. The reflection log allowed the player to self-assess motivation, effort, and emotional balance, while the coach evaluation provided an external perspective on engagement, discipline, and adaptation to the senior environment.

These tools generated a continuous feedback loop that informed the periodic revision of the PDP and PAP and provided contextual insights for interpreting quantitative changes over time.

RESULTS

Quantitative Findings

The quantitative results demonstrated a clear upward trajectory in both motivation and self-efficacy across the competitive season.

Table 1. M.O. Results at SMS II

Regulation Type	Items	Mean T1*	Mean T2	Mean T3	Δ* (T3–T1)	Interpretation
Intrinsic Regulation	3, 9, 17	4.8	5.6	6.3	+1.5	Growth in pleasure and curiosity toward performance learning; intrinsic satisfaction became the main driver.
Integrated Regulation	4, 11, 14	4.5	5.2	6.0	+1.5	Reinforcement of personal values and identity alignment with professional football.
Identified Regulation	6, 12, 18	5.0	5.5	6.2	+1.2	Strong and consistent motivation to use football as a means of self-development and growth.
Introjected Regulation	1, 7, 16	3.9	4.3	4.8	+0.9	Slightly increased internal pressure (guilt-driven motivation) but remains adaptive.
External Regulation	5, 8, 15	3.8	3.6	3.3	−0.5	Decline in reliance on external rewards or approval, indicating more autonomous motivation.
Amotivation (Non-Regulation)	2, 10, 13	2.9	2.4	1.8	−1.1	Reduced uncertainty and confusion about his role; stronger engagement and sense of purpose.
Overall Mean Score	1–18	4.16	4.43	4.73	+0.57	Progressive internalization of motivation toward self-determined regulation.

T1–Pre-season test; T2–mid-season test, T3–post-season test;* ***Δ**-difference between pre- and post-intervention scores.*

Scores from the Sport Motivation Scale II (SMS-II) showed a consistent internalization of motivation, with the most significant gains observed in intrinsic and integrated regulation. The athlete’s intrinsic motivation increased from 4.8 (T1) to 6.3 (T3), while integrated regulation rose from 4.5 to 6.0, reflecting a deeper internal alignment between personal values and athletic identity. Similarly, identified regulation increased from 5.0 to 6.2, confirming the athlete’s growing perception of football as a meaningful avenue for self-development.

In contrast, external regulation decreased from 3.8 to 3.3, and amotivation dropped substantially from 2.9 to 1.8, indicating a marked reduction in dependence on external rewards or approval. The overall mean SMS-II score improved from 4.16 at the beginning of the season to 4.73 at its conclusion, representing a 13.7% increase in self-determined motivation.

Table 2. M.O. Results at ASES

Subdimension	Items	Mean T1*	Mean T2	Mean T3	Δ* (T3–T1)	Interpretation
Sport Discipline Efficacy	1–4	3.1	3.7	4.4	+1.3	Steady improvement in technical-tactical confidence and physical readiness; visible adaptation to senior match pace.
Psychological Efficacy	5–8	2.9	3.8	4.5	+1.6	Strongest growth observed in emotional control and coping with pressure; improved self-motivation and leadership behavior.
Professional Thought Efficacy	9–12	3.3	3.9	4.2	+0.9	Gradual increase in planning and self-management; better training discipline and responsibility for individual goals.
Personality Efficacy	13–16	3.5	4.0	4.6	+1.1	Consistent progress in fair play, teamwork, and self-confidence; high sense of accountability at the end of the season.
Overall Mean ASES Score	1–16	3.2	3.8	4.4	+1.2	Clear upward trend in overall self-efficacy throughout the competitive year.

T1–pre-season test; T2–mid-season test, T3–post-season test;* ***Δ**-difference between pre- and post-intervention scores.*

Parallel trends were recorded in the Athlete Self-Efficacy Scale (ASES). The overall mean score rose from 3.2 (T1) to 4.4 (T3), signaling a substantial increase in perceived confidence across all performance domains.

The most pronounced improvements were observed in psychological efficacy (+1.6), sport discipline efficacy (+1.3), and personality efficacy (+1.1), suggesting greater emotional stability, composure under pressure, and maturity in interpersonal interactions. Notably, psychological efficacy progressed from 2.9 to 4.5, illustrating a 55% enhancement in emotional regulation and mental resilience.

These quantitative results closely align with the developmental milestones established in the Personal Development Plan (PDP) and Personal Action Plan (PAP). For instance, one of the athlete's targeted goals was to improve confidence during high-pressure match situations — an area that corresponds directly to the recorded increase in psychological efficacy and intrinsic motivation. The data therefore provide empirical confirmation that individualized, structured planning can accelerate psychological adaptation and readiness for senior-level competition.

Overall, the statistical pattern highlights a synergistic relationship between autonomous motivation and self-efficacy, consistent with self-determination theory (Deci & Ryan, 2000; Ryan & Deci, 2017). As motivation became more self-determined, self-efficacy increased in parallel, suggesting that the athlete's internal drive and perceived competence co-evolved through continuous reflection, feedback, and experiential learning in the senior environment.

Qualitative Findings

At the beginning of the season (T1), reflection entries indicated self-doubt and cognitive overload typical of players transitioning to senior-level competition. The athlete described difficulties in maintaining composure during high-intensity sessions and a tendency to overanalyze mistakes — patterns consistent with moderate ASES scores in psychological efficacy (2.9) and intrinsic motivation (4.8). A typical entry from August noted: "I feel pressure to prove myself every session. Sometimes I lose focus because I think too much about how I'm perceived."

Coach evaluations during this phase echoed these concerns, highlighting strong effort and tactical discipline but fluctuating emotional control under pressure. The coach noted: "Technically gifted, but visibly tense when challenged. Needs to channel energy into constructive self-talk and confidence."

By mid-season (T2), qualitative data reflected a clear shift in mindset. The athlete began identifying progress through self-reflection rather than external validation, in line with the rise in integrated and identified regulation on the SMS-II (from 4.5 to 5.2 and 5.0 to 5.5, respectively). Journal entries emphasized learning orientation and mental recovery: "I've started focusing on what I can improve after each session instead of what went wrong. Feedback helps me stay calm."

Coaches observed greater initiative, better emotional regulation, and improved communication with senior teammates. This behavioral change corresponded with the 0.9-point improvement in psychological efficacy and sport discipline efficacy, confirming a tangible link between reflection, motivation, and performance readiness.

By the end of the season (T3), qualitative indicators reflected a consolidated sense of professional identity and autonomy. Reflection logs from May and June contained statements such as: "I feel part of the team now. I know what's expected of me, and I can adapt without losing confidence."

This aligns with the athlete's high intrinsic motivation (6.3) and psychological efficacy (4.5) scores, suggesting internalized motivation and self-belief. The coach's evaluation described the athlete as "self-regulated, emotionally stable, and capable of leading transitions both technically and mentally."

These qualitative patterns mirror the statistical trends, demonstrating that the athlete's increased motivation and self-efficacy translated into observable psychological maturity, self-management, and adaptability — all core components of successful integration at the senior level. The interaction between reflective practice and structured feedback appears to have reinforced the athlete's internal motivational systems, validating the use of PDP and PAP as developmental scaffolds for both performance and personal growth.

Importantly, the longitudinal development observed throughout the 2024–2025 season culminated in a tangible performance outcome: in September 2025, the player made his official debut for FC Universitatea Cluj in Romania's top division (Liga I). This milestone represents the practical validation of the individualized PDP and PAP frameworks, indicating that psychological, motivational, and reflective growth translated effectively into readiness for professional competition.

DISCUSSION

The integrated analysis of motivational and self-efficacy data, supported by qualitative reflection and coaching evaluations, provides a holistic understanding of the athlete's adaptation during his first year of transition from youth to senior football. The convergence of findings from SMS-II, ASES and the qualitative instruments (Reflection Log and Coach Evaluation) illustrates a coherent developmental trajectory characterized by psychological growth, motivational internalization, and behavioral stabilization.

The systematic use of the PDP and PAP provided structure to this process by linking performance objectives with reflective self-assessment. Through regular review meetings, feedback sessions, and self-reflection logs, the athlete actively engaged in identifying strengths, weaknesses, and coping strategies — thus transforming learning into self-directed growth. This iterative cycle of goal setting, feedback, and adjustment mirrors the process of self-regulated learning described in athlete development literature (Morris et al., 2015; Rumbold et al., 2018).

Importantly, this study reinforces the idea that motivation and confidence do not evolve in isolation but through reciprocal interaction between the athlete and his environment. The club's supportive context — characterized by open communication, constructive feedback, and opportunities for senior-team exposure —

acted as a developmental facilitator. This finding resonates with Henriksen et al.'s (2010, 2013) ecological model of talent development environments, in which social support and psychological safety are foundational to sustainable performance.

Overall, the integrated findings suggest that individualized planning, continuous reflection, and a psychologically safe environment can collectively foster autonomous motivation, self-efficacy, and identity consolidation in athletes transitioning to senior football. This case illustrates how structured developmental frameworks like the PDP and PAP can be operationalized within club settings to bridge the gap between youth potential and professional performance readiness.

The implementation of the PDP and PAP functioned as a bridge between theory and applied practice. These tools translated abstract psychological constructs—such as motivation, self-efficacy, and emotional regulation—into concrete developmental goals and behavioral actions. By establishing short- and medium-term objectives, supported through feedback and reflection, the athlete experienced a structured yet flexible pathway for self-regulated learning. This supports existing literature emphasizing that clear goal orientation and reflective monitoring are core mechanisms of sustainable athlete development (Rumbold, Fletcher, & Daniels, 2018; Morris, Tod, & Oliver, 2015).

CONCLUSIONS

This single-case study provides empirical and applied evidence for how structured developmental planning—through the use of PDP and PAP—can effectively support the transition from youth to senior football. The integration of motivational (SMS-II) and self-efficacy (ASES) assessments with reflective and coaching feedback revealed a coherent pattern of psychological growth, enhanced intrinsic motivation, and improved self-regulatory capacity over the course of one competitive season.

The findings confirm that successful athletic transitions extend beyond technical and tactical readiness, encompassing deep psychological and social adaptation. When properly implemented within a supportive and psychologically safe environment, PDP and PAP frameworks can foster self-awareness, autonomy, and resilience—attributes that sustain both immediate performance and long-term professional identity. These results align with the holistic–ecological model of athlete development, illustrating how personal and contextual factors must operate in synergy to enable sustainable progress.

Notably, following a full competitive season of structured monitoring, feedback, and psychological support through the PDP and PAP frameworks, the player M.O. made his official debut in Romania's top division (Liga I) in September

2025 at FC Universitatea Cluj. This concrete outcome illustrates the potential effectiveness of individualized development and reflection-based approaches in bridging the gap between youth and professional football.

AUTHOR CONTRIBUTIONS

The first author was primarily responsible for the practical design and implementation of the intervention, data collection, and the interpretation of applied outcomes. The second author contributed to the theoretical foundation of the study and to the selection and justification of the psychological instruments. Both authors collaborated in structuring the manuscript and approved the final version for submission.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the conduct of this study or the publication of its findings.

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FROM CHAMPIONS TO CRISIS: COMMUNICATION MANAGEMENT AND LEADERSHIP TRANSITION IN ROMANIAN FOOTBALL

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ABSTRACT. *Introduction*: Crisis communication has become a central element of contemporary sports, where reputation and stakeholder trust are as fragile as athletic performance. The study focuses on FC Farul Constanța, a Romanian football club that experienced a rapid shift from national champion in 2023 to play-out participant in 2024, followed by a leadership transition in 2025, when Gheorghe Hagi stepped down as head coach to assume an administrative role. *Objective:* The research aimed to examine how the performance crisis of Farul Constanța was communicated publicly and how Gheorghe Hagi's personal brand influenced the perception of institutional stability during this period. *Material and Methods*: A qualitative case study approach was used, applying thematic content and discourse analysis to 85 public materials, including official club releases, media interviews, and social media posts from May 2023 to June 2025. The analytical framework was based on Coombs' Situational Crisis Communication Theory (SCCT) and personal branding principles. *Results*: Findings indicate that Farul's communication strategy relied heavily on Hagi's symbolic capital, combining emotional cohesion with limited strategic diversification. Public messaging oscillated between defensive justification and reaffirmation of identity values. *Discussion:* The study highlights the vulnerability of sports institutions dependent on charismatic leaders, where the overlap between personal and organizational

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reputation can both stabilize and constrain crisis management. *Conclusions:* Sustainable resilience in sports communication requires balancing individual charisma with institutional transparency and structured communication strategies, ensuring long-term trust and brand coherence.

Keywords: Crisis communication; Situational Theory of Crisis Communication; Romanian football; Gheorghe Hagi; personal branding.

INTRODUCTION

Sport communication is deeply symbolic and relational, reflecting not only performance but also identity and legitimacy. As Gomboș (2012, p. 34) observes, modern sport is structured around the act of "naming a winner," embedding competition within collective values. Hence, a crisis in sports communication signifies more than a loss — it becomes a challenge to institutional meaning and reputation.

In a broader perspective, Gherman, Monea, Gomboș and Pătrașcu (2021, p. 81) emphasize that leisure physical activity sustains a healthy lifestyle, a view aligned with Baciu (2015) and Prodea (2008), who interpret sport as an educational and social process shaping identity, balance, and cohesion. Thus, communication and leadership in sport are not only tools of performance but also vehicles for cultural meaning and social health.

In recent decades, theories of crisis communication have evolved significantly, moving from descriptive models to strategic approaches, in which organizations become active actors in managing their own vulnerabilities. Among the most influential theoretical models is the *Situational Crisis Communication Theory* (SCCT), developed by W. Timothy Coombs (2007), which provides an analytical framework based on the public perception of the organization's responsibility and the adequacy of response strategies to the type of crisis. The theory proposes a classification of crises according to the degree of responsibility attributed – from situations in which the organization is considered a victim, to preventable crises, where perceived responsibility is high.

In the sports context, crisis communication acquires specific valences, since the organizational reputation often overlaps with the personal image of leaders and coaches. Football organizations, in particular, are exposed to constant pressure from the media, supporters and sponsors, and fluctuations in sports performance can generate real image crises (Pegoraro & Frederick, 2021). Thus, sport offers a privileged framework for observing how communication becomes not only a management tool, but also one for reconfiguring public identity.

The case of Farul Constanța is relevant from this perspective, as it reflects a complex transition: from the success achieved in 2023, when the team became the Romanian champion, to the period of sporting decline the following season and, subsequently, to the retirement of Gheorghe Hagi as coach in 2025. This evolution provides a fertile framework for analyzing how communication strategies have been adapted, and the image of the leader – strengthened through storytelling and personal branding mechanisms, especially through the publication of his autobiography.

Therefore, the purpose of this study is to analyze the crisis communication strategies used by the Farul Constanța and by Gheorghe Hagi, through the prism of the SCCT theory, complemented by the concept of personal branding. The research aims to identify the type of crisis, the degree of perceived responsibility, the response strategies used, and how the leader's personal narrative contributed to managing the transition and protecting organizational reputation.

General Context

Crisis is defined by Coombs (1998, cited in Upadhyay & Upadhyay, 2023) as "an unpredictable event, a major threat that can produce negative effects on the organization, industry, or stakeholders, if inadequately managed." Hence the importance of communication as a tool for managing perceptions and protecting reputation.

Crisis communication is a strategic process through which organizations manage unexpected situations that can threaten reputation, public trust and institutional stability (Coombs, 2015). It involves not only the rapid and coherent transmission of information, but also the building of a relationship of trust with key audiences, by assuming responsibility, transparency and consistency in actions. Organizational crises are inevitable events, but the organization's reaction often determines the public perception of its degree of professionalism and credibility.

The Situational Crisis Communication Theory (SCCT), formulated by W. Timothy Coombs (1995, 2023), represents one of the most influential theoretical frameworks in the field. It starts from the premise that the public's perception of the organization's degree of responsibility determines the choice of communication strategy. The greater the perceived responsibility, the stronger the negative effect on reputation (Coombs & Holladay, 1996).

Coombs' situational model is based on the idea that the match between the type of crisis and the response strategy is decisive for the success of communication. Empirical studies show that the use of inappropriate strategies, such as denial in cases where responsibility is obvious, can aggravate the crisis and produce significant reputational losses (Coombs & Harker, 2021).

In sport, crisis communication has a particular dimension, as the reputation of sports organizations is often closely linked to the identity and image of leaders or coaches. Performance crises, internal conflicts, controversial decisions or the relationship with supporters can trigger intense emotional reactions, and their management requires strategies adapted to the specific context of the field (Pegoraro & Frederick, 2021). In this sense, traditional communication models intersect with elements of leadership, storytelling and personal branding, which makes the theoretical approach complex and integrative.

In the field of sport, the application of the SCCT is particularly relevant, as athletes and sports organizations are exposed to intense public visibility, and public perceptions are quickly formed through the media and social networks. Sports crises differ from classic organizational crises in that the main actor – the athlete, the team or the coach – is directly in the public spotlight, and the impact on trust and reputation is immediate (Pöppel & Strauss, 2024).

Typologies Of Crises and Determinants of Public Perception

Within SCCT, Coombs (2007; 2023) proposes a tripartite classification of crises, based on the public's perception of the organization's degree of responsibility. This classification provides an essential analytical tool for choosing the appropriate communication strategies for each situation.

1. Crises in which the organization is perceived as a victim- Victim crises arise when organizations face external and uncontrollable events with minimal perceived responsibility, such as natural disasters, sabotage, or misinformation (Coombs, 2023). In sports, these may include refereeing errors, cyberattacks, suspended competitions, or unfounded media accusations. In such cases, communication focuses less on defending reputation and more on restoring solidarity and empathy. As Andersen, Moldenæs, and Ronglan (2022) argue, when a team is perceived as a "victim of context," effective messaging emphasizes collective values, unity, and resilience, using bolstering strategies that turn vulnerability into identity reinforcement.

2. Accidental crises- These crises stem from unintended events with partial organizational responsibility, such as management or administrative errors, technical negligence, or internal miscommunication (Pöppel & Strauss, 2024). In sports, they often manifest through inappropriate statements, procedural failures, or coordination issues. The appropriate response is a diminish strategy, in which the organization acknowledges the incident while explaining mitigating factors (Coombs, 2007). As Bundy et al. (2017) note, the effectiveness of this approach depends largely on pre-existing credibility—organizations with a strong reputation are more likely to maintain public trust when such incidents occur.

3. Preventable crises - pose the highest reputational risk, as they imply clear managerial, moral, or ethical responsibility (Coombs & Holladay, 1996). In sports, they result from intentional or negligent actions such as financial fraud, doping, match-fixing, or abuses of authority. Coombs (2023) recommends rebuild strategies, which emphasize accountability, apology, and corrective action. When organizations deny guilt, reputational damage intensifies and trust becomes difficult to restore (Bundy et al., 2017). Pöppel and Strauss (2024) highlight that such strategies are most effective when led by credible figures embodying organizational values—as illustrated by Gheorghe Hagi and Farul Constanța, where the leader's image is inseparable from that of the club.

Main Response Strategies

Coombs (2023) proposes four strategic postures: *Denial posture* – rejecting the existence of the crisis or identifying a scapegoat; *Diminishment posture* – reducing the perceived severity of the crisis through excuses or justifications; *Rebuilding posture* – assuming responsibility and offering an apology; *Bolstering posture* – reinforcing a positive image by recalling past achievements or portraying the organization as a victim.

According to Coombs' Situational Crisis Communication Theory (SCCT), responses must align with the perceived degree of responsibility. The denial strategy suits "victim" crises, aiming to refute false claims or correct misinformation, though excessive use amid clear fault can harm credibility (Coombs & Holladay, 1996). In accidental crises, organizations employ diminishment strategies, providing contextual explanations and showing empathy and preventive intent (Bundy et al., 2017). When responsibility is clear, rebuilding strategies—centered on apology, accountability, and corrective action—are required, with their success depending on authenticity and consistency (Pöppel & Strauss, 2024). Beyond these, bolstering strategies (Coombs, 2023) reaffirm identity through values, legacy, and emotional bonds, proving particularly effective in sport, where fan loyalty and symbolism are central (Andersen, Moldenæs & Ronglan, 2022).

Personal Branding and Strategic Storytelling in Leadership Transition

In elite football, where visibility is constant and public scrutiny immediate, the personal brand of coaches and players shapes how organizational performance is perceived (Parmentier & Fischer, 2012; Pegoraro & Frederick, 2021). During crises, individual reputation can buffer institutional decline and sustain audience engagement around a coherent identity (Andersen, Moldenæs & Ronglan, 2022; Pöppel & Strauss, 2024).

Gheorghe Hagi exemplifies an organically built personal brand, grounded in performance, value consistency, and symbolic authenticity. Over a career spanning Europe's top clubs — Steaua București, Real Madrid, FC Barcelona, and Galatasaray — he has evolved from a player into a transgenerational brand combining excellence, modesty, and perseverance. His image avoids spectacle and controversy, relying instead on national symbolism and moral authority, embodying the principles of education through sport and professional integrity (Parmentier & Fischer, 2012).

Aligned with Pöppel and Strauss (2024), Hagi's personal brand functions institutionally, merging with Farul Constanța's identity; the club's reputation reflects his values of discipline, meritocracy, and community engagement. His autobiography (*Hagi – My Road*, 2025) marks a moment of symbolic reinforcement, consistent with Smith and Watson's (2010) theory of autobiographical legitimation. The book reframes his career not as an ending but as a continuity of purpose — shifting from active coaching to a role as architect of a moral and educational sports philosophy.

MATERIAL AND METHODS

Research Aims and Questions

The main purpose of the research is to analyze how crisis communication and personal branding strategies intersected during the leadership transition at Farul Constanța club, between 2023–2025. The study explores the way in which Gheorghe Hagi, as a leader and institutional symbol, discursively managed a period of sporting decline and identity reconfiguration through strategic communication tools, both at individual and organizational level.

The specific objectives pursued are:

1. Identification of the type of crisis (according to the SCCT framework) in which the Farul Constanța club found itself after the 2023–2024 season.

2. Analysis of the communication strategies used in the public space by the club and by Gheorghe Hagi.

3. Interpreting the transition process from the role of coach to that of administrative leader as a personal rebranding and reputational stabilization strategy.

Based on these objectives, the research was guided by the following questions:

1. How does the performance crisis of Farul Constanța (2023–2025) manifest itself and what is the degree of perceived responsibility according to the SCCT classification (Coombs, 2023)?

2. What crisis communication strategies can be identified in the public speeches of the club and of Gheorghe Hagi, during the period of sporting decline?

Research Design

The study begins on May 21, 2023, when Farul Constanța won the Romanian championship under Gheorghe Hagi's leadership — a moment representing both the peak of sporting achievement and symbolic credibility for the club and its leader. The following season (2023–2024) marked the onset of decline, as the team barely qualified for the play-offs and finished fourth. The downward trajectory continued in 2024–2025, with Farul competing in the play-outs and finishing third there, reinforcing the perception of a performance crisis.

In June 2025, Hagi announced his retirement as coach and transition to an administrative role, closing the analyzed period and symbolizing a shift from sporting glory to identity reconstruction.

The research employs qualitative content analysis applied to 85 public materials, including: (a) official club releases; (b) Hagi's post-match statements and interviews; and (c) fan reactions on the official Facebook page, which serve as indicators of public sentiment and perception. Facebook was chosen as the main platform given its dominance in Romanian digital culture and its centrality in sports communication, storytelling, and reputation management (Sanderson, 2022; Pegoraro & Jinnah, 2023).

Data were analyzed through a thematic-comparative approach, correlating event chronology with Coombs' (2023) SCCT postures — denial, diminishment, rebuilding, and bolstering — to trace the evolution of crisis communication strategies across the two-year period.

Data analysis

The analytical approach focuses on tracing the coherence and evolution of crisis discourse, highlighting how tone, themes, and communicated values shifted alongside changes in sporting context. In the first stage (May 2023), both the club and Hagi employed a bolstering strategy, centered on celebrating success, reinforcing symbolic capital, and promoting educational values.

During the 2023–2024 season, when Farul barely secured a play-off spot and finished fourth, the discourse introduced elements of diminishment — rational explanations, emphasis on injuries, and calls for patience — signaling the early phase of the performance crisis, while maintaining a controlled and non-defensive tone.

Between March and June 2025, as Farul competed in the play-out and finished third, coinciding with Hagi's retirement as coach, communication shifted toward rebuilding and bolstering. This stage articulated an identity-centered narrative grounded in loyalty, work, and modesty, reaffirming the club's symbolic role as an educational and community-driven project.

The findings, summarized in a comprehensive table, allow a comparative analysis of institutional (club) and personal (Hagi) communication, revealing how the two brand identities strategically interacted to sustain narrative coherence and preserve public trust throughout the crisis.

Table 1. Content Analysis of Posts and Public Statements
(Farul Constanța & Gheorghe Hagi, 2023–2025)

Date	Source / Context	SCCT Strategy	Observations / Interpretation
May 21, 2023	Official Facebook post – the announcement of the championship title	*Bolstering*	Euphoric and symbolic speech; emphasis on collective pride and identity. Record level of engagement (17K reactions).
May 21, 2023	Statement by Gheorghe Hagi (Digi Sport)	*Bolstering*	Motivational narrative based on moral values (work, faith, character).
May 22, 2023	Official press release – Farul Constanța website	*Bolstering*	Institutional communication focused on unity and gratitude.
May 24, 2023	Facebook post – articles from the international press	*Bolstering*	External validation of success through international recognition.
May 24, 2023	Facebook post – comparative image Hagi 1982 / 2023	*Bolstering*	Narrative of continuity between past and present.
May 29, 2023	Official press release – Farul Constanța website after the match against CFR Cluj	*Diminish*	Moderated speech, focused on consistency and responsibility.
May 29, 2023	Facebook post – GSP's awards of the month ("Farul takes it all!")	*Bolstering*	Reaffirmation of prestige through external recognition.
June 3, 2023	Facebook post – All Star Romania vs. Galatasaray Legends exhibition match	*Bolstering*	Consolidation of Hagi's personal prestige through nostalgia.
June 28, 2023	Facebook post – Hagi named "Coach of the 2022–2023 season"	*Bolstering*	Close the successful speech with a ceremonial tone.
July 8, 2023	Facebook post – defeat in the Romanian Super Cup	*Diminish*	The first signal of the decline in performance. Sober but positive tone.
July 9, 2023	Statement Gheorghe Hagi – after losing the Super Cup	*Diminish*	Rational tone, reinterpretation of failure as a learning process.
July 13, 2023	Official press release – Farul Constanța website after the victory against Sheriff	*Diminish / Bolstering*	Balance between optimism and realism. Consolidation of core values.
July 18, 2023	Facebook post – "Our journey in Europe continues in the Conference League"	*Diminish*	Recontextualizing failure as a "continuation of the road".

Date	Source / Context	SCCT Strategy	Observations / Interpretation
July 19, 2023	Gheorghe Hagi Conference – after the match in Tiraspol	*Rebuild*	Explicit assumption of responsibility.
July 22, 2023	Official press release – Farul Constanța website - Hagi's conclusions after the victory against Voluntari	*Rebuild*	Critical discourse, oriented towards discipline.
July 30, 2023	Official press release – Farul Constanța website – Hagi conclusions after the failure against Iasi	*Rebuild*	Self-criticism and reaffirmation of the values of modesty and work.
August 6, 2023	Facebook post – “We lose in extra time in Ploiesti.”	*Diminish*	Minimal communication, aimed at reducing negative exposure.
August 16, 2023	ProSport article – reactions after controversial qualification	*Bolstering / Rebuild*	Media debates become a symbolic resource.
August 25, 2023	Official press release – Farul Constanța website – Hagi's reactions after Helsinki	*Bolstering*	Return to positive discourse and cohesion.
August 30, 2023	Article OrangeSport – criticism after the elimination with HJK	*Rebuild*	External criticism highlights questionable choices; calm management.
September 3, 2023	Facebook post – after the defeat against Universitatea Craiova	*Diminish*	Short, impersonal message, strategy to reduce exposure.
September 11, 2023	Official press release – Rivaldo becomes a shareholder in Farul Constanța	*Rebuild / Bolstering*	Strategic movement to relaunch reputation.
September 18, 2023	Facebook post – Hagi, after the match against FCSB	*Diminish*	Redirecting attention to external factors (arbitration).
September 22, 2023	Facebook post – “Important victory in the Capital.”	*Bolstering*	Return to the triumphalist tone. Strengthening team morale.
September 26, 2023	Facebook post – “Defeat at Voluntari in the Romanian Cup.”	*Diminish*	Neutral communication, without justification. Strategy to avoid overcommunication in a negative context.
September 29, 2023	Official press release – Farul Constanța website – Hagi's statements prior to the match against Sepsi	*Rebuild*	Anticipatory and balanced speech. It conveys control and trust, marking the return to a rational and preventive tone.
October 10, 2023	Facebook post – “Gheorghe Hagi, the coach of the 12th round”	*Bolstering*	Return to external validation and reaffirmation of personal prestige. The club capitalizes on the individual recognition of the leader.
October 26, 2023	Official press release – “Hagi Academy, offered as an example at the FIFA Congress”	*Bolstering/ Rebuild*	International recognition presented as a symbolic validation of the project. In a period of sporting instability, the club is redirecting the discourse towards values of sustainability and long-term vision.

Date	**Source / Context**	**SCCT Strategy**	**Observations / Interpretation**
October 30, 2023	Facebook post – "First failure in the last six games!"	*Diminish*	Neutral and short tone. The "first failure" formula minimizes the negative impact by emphasizing the previous positive series.
November 1, 2023	Facebook post – "Galata TV visited the Hagi Academy"	*Bolstering*	The post symbolically reactivates Hagi's connection with Galatasaray, strengthening international emotional capital. External recognition has the role of reputational validation and diversification of the public narrative at a time of fragile balance of sports performance.
November 5, 2023	Gheorghe Hagi Conference – after the match against Botoșani (1–1)	*Rebuild/ Diminish*	Reaffirmation of the collective effort, justification by lack of resources.
November 25, 2023	Facebook post – "Even in difficult times, Pharisees remain united!"	*Bolstering/ Diminish*	Emotional mobilization, call for unity.
December 16, 2023	Gheorghe Hagi Conference – after 0–0 against UTA	*Diminish*	Balanced assessment, moderate justifications.
December 20, 2023	Facebook post – "Equal with Rapid. Constanta, don't forget! 2023 was a historic year!"	*Bolstering*	Remembering successes as a strategy of symbolic consolidation.
December 21, 2023	Gheorghe Hagi Conference – after Farul–Rapid 0–0	*Rebuild/ Diminish*	Discourse on Transition and Reputational Reconfiguration.
December 27, 2023	Facebook post – annual review "2023 – a historic year"	*Bolstering (maximum)*	Narrative synthesis post: reconstructs the image of the club by accumulating merits (sporting, institutional, symbolic). It reorients the public's attention from recent results to vision and project.
January 27, 2024	Facebook post – "Gheorghe Hagi, happy after a new success"	*Bolstering*	Positive tone, reaffirmation of control and internal cohesion.
February 6, 2024	Official press release – Farul Constanța website – Gheorghe Hagi's conclusions after the 1–1 draw against FCSB	*Diminish/ Rebuild*	Balanced analysis, call for inspiration and confidence.
February 9, 2024	Facebook post – "Gheorghe Hagi, the best coach of the 2022–2023 season"	*Bolstering*	Strengthening reputation and professional authority.
February 13, 2024	Facebook post – "We remain united!"	*Bolstering/ Diminish*	Emphasis on unity and team spirit.
February 14, 2024	Facebook post – "Emotional meeting for Dumi"	*Bolstering (emotional)*	Humanizing and strengthening the relationship with fans.
March 8, 2024	Facebook post – "The result needed to qualify for the play-offs"	*Rebuild/ Bolstering*	Reinterpreting success as a strategic outcome.

Date	Source / Context	SCCT Strategy	Observations / Interpretation
March 29, 2024	Official press release – Denial of rumors regarding Hagi's departure	*Deny*	Managing a reputational mini-crisis through transparency.
April 1, 2024	Official press release – Farul Constanța website – Hagi's conclusions after the match against FCSB	*Diminish / Bolstering*	Balance between self-criticism and optimism.
April 6, 2024	Official press release – Farul Constanța website – Hagi's conclusions after 1–1 against Sepsi	*Rebuild/ Diminish*	Moderate assumption and call for balance.
April 15, 2024	Facebook post – "I am non-transferable to Romania"	*Bolstering (identitarian)*	Reaffirmation of loyalty and symbolic consolidation of the Hagi-Farul brand.
May 3, 2024	Facebook post – "Final result. Mandatory before!"	*Rebuild / Bolstering (defensive)*	Message of resilience and narrative control in the face of failure.
May 14, 2024	Official press release – Farul Constanța website – Gheorghe Hagi's conclusions after the match against Univ. Craiova	*Rebuild (explainer)*	Causal analysis and promise of reconstruction.
May 18, 2024	Facebook post – "The Mariners finish the season in 4th place"	*Diminish / Bolstering*	Normalization of the result, neutral tone.
May 21, 2024	Facebook post – "Images for history! A year ago..."	*Bolstering (nostalgic/ symbolic)*	Reactivation of positive collective memory.
July 11, 2024	Official press release – Farul Constanța website – Gheorghe Hagi prefaced the first game of the new season	*Rebuild / Diminish (pre-crisis)*	Realistic anticipation of difficulties, preemptive speech.
July 12, 2024	Facebook post – "Final result" (0–1 defeat against Slobozia)	*Diminish / communicative minimalism*	Lack of contextualization, avoidance strategy.
August 18, 2024	Press conference – "I was the first to believe in Farul"	*Rebuild / Bolstering (Defensive Leadership)*	Self-justification and delimitation of responsibility, reaffirmation of the founding role.
September 4, 2024	Official press release – Farul Constanța website – Inauguration of the new facilities of the Hagi Academy	*Bolstering (institutional)*	Change of focus: symbolic consolidation through structural development.
September 26, 2024	Facebook post – "The kick-off given by Petrică, an injured fan"	*Bolstering (Emotional/ Community)*	Post with an emotional impact, which reactivates community solidarity and humanizes the brand.

Date	Source / Context	SCCT Strategy	Observations / Interpretation
September 30, 2024	Official press release – signing of the document for the new stadium	*Bolstering/ Rebuild*	Major infrastructure announcement, used as a tool for reputational consolidation and repositioning of the club.
October 5, 2024	Official press release – Farul Constanța website – Gheorghe Hagi's statements after 1–1 against Dinamo	*Rebuild/ Diminish*	Balanced speech between frustration and motivation.
October 22, 2024	Official press release – “Farul denies the Hagi-Popescu conflict”	*Deny*	Prompt reaction to rumors in the press about an internal conflict.
November 3, 2024	Facebook post – “We return with a point from the leader's field” (1–1 against U Cluj)	*Bolstering/ Diminish*	Restrained, but positive tone: it stands out to get a point on the leader's court, to maintain the perception of stability and progress.
November 3, 2024	Facebook post – “We return with a point from the leader's field” (1–1 against U Cluj)	*Bolstering/ Diminish*	Restrained, but positive tone: it stands out to get a point on the leader's court, to maintain the perception of stability and progress.
November 29, 2024	Facebook post – “We worked 90 minutes to return home with 1 point”	*Diminish/ Bolstering (resilience)*	Concise post, with an emphasis on effort and solidarity. The lack of tactical or contextual comments indicates a minimalist communication strategy, aimed at protecting the internal image and diminishing the perception of a sports crisis.
December 16, 2024	Official press release – Farul Constanța website – Conclusions of manager Gh. Hagi after the 1–1 draw against FCSB	*Rebuild/ Diminish (realistic self-assessment)*	Hagi highlights the lack of consistency and offensive inefficiency, but maintains a constructive tone, with a focus on confidence in his own potential. The communication strategy is based on moderate transparency and the appeal to internal values (patience, faith, work).
January 1, 2025	Facebook post – “Happy birthday, Pharisees! Let's move forward together!”	*Bolstering (motivational / identity)*	Reaffirming the collective spirit and identity of the club.
January 20, 2025	Facebook post – Hagi and Rednic – “208 selections for the Romanian national team.”	*Bolstering (symbolic association)*	Consolidation by reference to the elites of Romanian football.
January 27, 2025	Facebook post – “Defeat in Gruia.”	*Diminish (minimization)*	Neutral tone, factual communication without dramatization.
February 3, 2025	Official press release – Farul Constanța website – The best scorers in the history of the national team.”	*Bolstering (historical)*	Historical legitimacy by association with national performance.
February 5, 2025 (I)	Facebook post – Hagi anniversary	*Bolstering (emotional)*	Reaffirmation of internal unity and the value of the leader.

Date	Source / Context	SCCT Strategy	Observations / Interpretation
February 5, 2025 (II)	Official press release – Farul Constanța website – Launch of the autobiography "*My Road*"	*Bolstering & Rebuilding (storytelling)*	Authenticity and narrative reconstruction of the personal brand.
8 March 2025	Official press release – Farul Constanța website – Gh. Hagi's conclusions after the match against U Cluj.	*Rebuilding*	Adaptation to the play-out context, lucid and pedagogical tone.
March 12, 2025 (I)	Official press release – Farul Constanța website – "Our program in play-out."	*Bolstering (normaliza-tion)*	The natural continuation of the sporting path.
March 12, 2025 (II)	Official press release – website Farul Constanța – Hagi Decorated with the National Order "Star of Romania"	*Bolstering (institutional legitimation)*	Symbolic reconfirmation of the leader's value and prestige.
March 19, 2025	Facebook post – The autobiographical book Hagi – *My Road* available for pre-order	*Bolstering (storytelling)*	Strengthening narrative and emotional capital.
March 24, 2025	Official press release – Farul Constanța website – Farul – Miniso Partnership.	*Bolstering (reputational partnership)*	Association with an international brand for stability image.
March 26, 2025	Facebook post – Launch of the autobiography *Hagi – My Road* to ASE Bucharest."	*Bolstering & Rebuilding*	Reconnecting with the national public through education and values.
April 12, 2025	Official press release – Farul Constanța website – Gh. Hagi's conclusions after the victory against Sepsi.	*Rebuilding (recovery and optimism)*	Return to the tone of confidence and performance.
April 19, 2025	Official press release – Farul Constanța website – Gh. Hagi's conclusions after the match against Hermannstadt.	*Rebuilding*	Analytical message, oriented towards improving the game.
April 24, 2025	Facebook post – "End of the road." (elimination from the Romanian Cup)	*Diminish / Transition*	A succinct, symbolic message – the closing of a chapter.
May 3, 2025	Official press release – Farul Constanța website – Gh. Hagi's conclusions after the victory against Gloria Buzău.	*Rebuilding (construc-tive criticism)*	Self-criticism, awareness of limits and requirement of discipline.
May 4, 2025	Facebook post – Legendary meeting between Gheorghe Hagi and Cafu.	*Bolstering (global identifica-tion)*	International recognition, personal brand validation.
May 10, 2025	Official press release – Farul Constanța website – Gh. Hagi's conclusions after the match against UTA.	*Rebuilding Repositioning (reflexive)*	Transition discourse – orientation towards structural reform.

Date	Source / Context	SCCT Strategy	Observations / Interpretation
May 17, 2025	Official press release – Farul Constanța website – Gh. Hagi's conclusions after the 0-0 draw against Oțelul.	*Rebuilding (strategic closure)*	Calm season closing, call for analysis and new energy.
May 21, 2025	Facebook post – The day we became the champions of Romania.”	*Bolstering (nostalgic/ symbolic)*	Re-anchoring in the glorious past to regain cohesion.
May 23, 2025	Facebook post – Launch of the autobiography *Hagi – My Road* to Constanta.”	*Bolstering (community storytelling)*	Cultural and affective event, reaffirmation of the connection with the city.
June 2, 2025 (I)	Facebook post – The autobiographical album *Hagi – My Road* available in Farul stores and online.	*Bolstering (institutionalization of the brand)*	Strategic continuity between the personal image and that of the club.
June 2, 2025 (II)	Official press release – Gheorghe Hagi announces the termination of the mandate of technical manager of the Farul team.	*Rebuild Reposition-ing (transition and continuity strategy)*	The statement marks the end of his technical role, but also the redefinition of the position in the club, from coach to mentor / strategist. Calm, dignified, future-oriented tone. Key moment to close the 2023–2025 cycle and protect the image.

RESULTS

2023 – From the peak to the first signs of the crisis

The year 2023 marks the peak of sporting and symbolic performance for Farul Constanța, a team that wins the national championship under the leadership of Gheorghe Hagi. The public communication during this period reflects a “bolstering” strategy, in which the focus is on strengthening the reputation, celebrating success and associating the club's brand with the values of work, modesty and unity. The posts from May 2023 highlight a record fan interaction (thousands of reactions and shares), confirming that the image of the club and Hagi is in a period of public glory.

After this climax, the first signs of instability begin to appear. The defeat in the Romanian Super Cup (July 2023), followed by elimination from European competitions, triggers a change of tone: official messages remain optimistic, but increasingly include justifications and appeals for patience (“we are at the beginning of the road”, “we have many injured players”). This discourse is part of the “diminish” strategy, specific to the early stages of a performance crisis, in which actors try to minimize the severity of the situation and invoke contextual factors.

As the results become more and more oscillating, and the team loses the consistency of performance, Hagi resorts to a "rebuilding" type of communication, acknowledging mistakes ("we made a fool of ourselves", "we have to become modest again") and implicitly assuming responsibility. Towards the end of 2023, the discourse stabilizes on a reflective and moral register, in which the appeal to "modesty", "work" and "faith" becomes central. The club is trying, through a retrospective message (post of December 27, 2023), to symbolically reconfigure the year as "historic", transforming the sporting decline into a narrative of perseverance.

Thus, 2023 can be considered the transition stage from consolidation to decline, in which the crisis is not yet assumed as such, but manifests itself through tensions between the image of success and the sporting reality.

2024 – Organizational crisis and image test

In 2024, Farul is going through a period of accumulated performance crisis, with unstable results and a decrease in public trust. Communication becomes a tool for symbolic management of organizational fragility. The first part of the year is dominated by Hagi's messages that maintain a balanced tone: emphasis on "inspiration", "unity" and "hard road". Communication is mainly part of the "rebuilding" strategy, which tries to regain trust through transparency and appeal to values.

However, the key moment of the year is represented by the press release of March 29, 2024, in which Hagi denies the information regarding a possible departure from the club. Through this intervention, he explicitly applies a "deny" strategy, designed to protect the perceived stability of the organization and reassert control over the public narrative. Subsequently, through the statements of April-May 2024, the tone becomes more and more critical of the internal conditions ("incredible injuries", "I can't make a team"), and Hagi openly assumes the position of leader under pressure. A crisis of resources and authority is thus taking shape, doubled by a visible organizational fatigue.

A moment of rupture is represented by the statement in August 2024, in which Hagi announces that he will reduce his financial and majority shareholder involvement. This episode marks the transition from a sports performance crisis to an institutional and identity one, in which the continuity of the Hagi management model is raised. The official communication, however, maintains a moderate and encouraging tone, appealing to the image of the Hagi Academy and investments in infrastructure (post of September 4, 2024). Thus, the discourse is strategically repositioned towards symbolic bolstering, by emphasizing sustainable values (youth training, educational performance), which attenuates the perception of immediate decline.

2025 – Transition and symbolic reconfiguration

The year 2025 brings a radical change of narrative: communication focuses on rehumanizing the image of Gheorghe Hagi and consolidating his legacy as a symbol of Romanian football. Although the team is in the play-out and the sports performance is modest, the focus shifts to the identity and emotional dimension.

The publication of the autobiography “Hagi – My Road” (March 2025) works as a strategic personal storytelling tool, which transforms a period of crisis into a process of symbolic reconnection with the public. The launch of the book is widely reflected on the club's official channels and produces a wave of empathy, repositioning Hagi not as a coach in difficulty, but as a figure-legend, with a mission accomplished. This is part of the “bolstering” strategy, with an emphasis on moral values, personal example and institutional recognition (decoration with the Order of the “Star of Romania”).

In June 2025, with the announcement of his retirement from the technical leadership, Hagi completes a coherent communicative transition, from justification to resignification. The crisis is not over at the organizational level, but the leader's image is already positively reconfigured. The club's official discourse maintains the tone of symbolic continuity, invoking the values of work and loyalty. Thus, the year 2025 marks the stage of transforming an image crisis into a process of personal rebranding, in which storytelling becomes the main mechanism of reputational protection.

Anticipatory analysis of fan reactions online (2023–2025)

In 2023, fan discourse was dominated by euphoria and belonging. Posts celebrating the championship title and Hagi’s leadership attracted hundreds of affirmative comments such as *“You made history for Constanța!”* or *“Farul is family, Hagi is our symbol!”*, signaling maximum cohesion between supporters and the club.

During 2024, the tone shifted as inconsistent results and repeated injuries led to a mix of encouragement (*“Head up, Mister, let’s move forward!”*) and criticism (*“Enough excuses, where’s last year’s team?”*). The community divided between loyalists and skeptics, though posts emphasizing long-term projects — especially those related to the academy — continued to elicit positive engagement, indicating trust in developmental narratives.

By 2025, following Hagi’s autobiography launch and national distinction, the online environment regained harmony. The discourse became warm and reverential, with comments such as *“Respect, King of Romania!”* reaffirming collective admiration. The shift from crisis to homage demonstrates how personal storytelling and authenticity can neutralize tension and restore symbolic capital.

Overall, the digital discourse evolved from identity-based euphoria (2023) to emotional polarization (2024) and, finally, to re-legitimation and empathy (2025). Through coherent and emotionally intelligent communication, Farul Constanța and Gheorghe Hagi preserved community trust, proving that in modern sport, reputation depends less on immediate success and more on the ability to transform collective emotion into enduring symbolic value.

DISCUSSION

The findings of this study are consistent with previous research showing that crisis communication in elite sport is strongly shaped by the symbolic authority of charismatic leaders. Schei et al. (2023) demonstrate that national team coaches often rely on identity-based and value-driven narratives during periods of instability, emphasizing unity, continuity, and moral legitimacy rather than technical explanations. A similar pattern is evident in the Farul Constanța case, where Gheorghe Hagi's discourse privileged collective values and long-term vision over short-term performance justifications, particularly in the later stages of the crisis.

The evolution of Gheorghe Hagi's communication throughout the analyzed period demonstrates the consolidation of a personal brand defined by authenticity, perseverance, and symbolic stability, anchored in a dual identity: sports leader and moral model.

In 2023, his image was inseparable from Farul Constanța's championship success, and his discourse projected charisma, discipline, and inspiration. The Hagi brand merged with the club's, creating a unified narrative of excellence and professionalism that strengthened both personal and institutional reputation.

During 2024, amid inconsistent results and growing pressure, Hagi's communication adopted a tone of realism and composure. He maintained public trust through honesty, restraint, and emphasis on values such as work, modesty, and loyalty. Rather than damaging his image, this phase humanized his brand, revealing a leader capable of navigating adversity without theatricality or blame.

Moreover, the strong overlap between Hagi's personal brand and the club's institutional identity confirms observations by Pegoraro and Frederick (2021), who argue that sport organizations frequently personalize crises through highly visible leaders, transforming organizational issues into reputational tests of individual credibility. While this personalization can stabilize public trust in the short term, it also increases vulnerability, as institutional legitimacy becomes dependent on the leader's symbolic capital. The Farul case illustrates this dual effect: Hagi's reputation buffered the crisis but simultaneously limited the development of an autonomous institutional voice.

In 2025, the publication of his autobiography *My Road* and the conferment of the National Order "Star of Romania" marked a strategic repositioning of his brand — from an active coach to a symbolic figure of national heritage. His autobiographical narrative functioned as a tool of storytelling and re-legitimation, reinforcing moral authority and preserving legacy beyond sporting performance.

The study also supports Coombs' (2023) assertion that diminishment strategies are most effective in performance-related crises when responsibility is framed as contextual rather than intentional. By emphasizing injuries, financial constraints, and structural limitations, Farul's communication aligned with what Bundy et al. (2017) identify as credibility-preserving explanations, particularly effective when the organization benefits from a strong pre-crisis reputation. Hagi's consistent emphasis on work, patience, and education reinforced this credibility, preventing escalation into a preventable-crisis perception.

Finally, the strategic use of autobiographical storytelling as a reputational buffer resonates with Smith and Watson's (2010) theory of autobiographical narratives as tools of identity legitimation. Similar to findings reported by Pöppel and Strauss (2024), the leader's symbolic repositioning—from operational actor to moral reference—allowed the crisis to be reframed as a transitional moment rather than a failure. In this sense, the Farul case confirms that, in sport, crisis communication effectiveness depends not only on message-content alignment with SCCT postures, but also on the leader's ability to mobilize narrative continuity and emotional resonance.

Overall, Hagi's brand remains authentic, coherent, and value-driven, blending sporting credibility, moral integrity, and emotional resonance. Despite fluctuations in results, his consistent focus on work, passion, and humility transformed a period of crisis into a moment of identity reaffirmation and enduring symbolic strength.

The comparative analysis of Gheorghe Hagi's personal brand and Farul Constanța's institutional brand reveals an initial phase of symbiosis, followed by a gradual differentiation in public perception.

Between 2023 and 2024, the two identities were fully aligned — performance, discourse, and values (work, modesty, perseverance, faith) converged into a single narrative. Farul's legitimacy largely stemmed from Hagi's personal credibility, as he embodied the club's leadership and symbolic authority.

In 2024–2025, amid declining results and Hagi's retirement from coaching, the relationship evolved toward strategic separation. The club adopted a more institutional tone, seeking autonomy, while Hagi repositioned himself as a national and moral figure, reinforced by his autobiography. The crisis thus acted as a moment of redefinition, transforming Hagi into a cultural symbol and Farul into his enduring sporting legacy.

CONCLUSIONS

The analysis of the 85 materials published between May 2023 and June 2025 confirms that Farul Constanța's performance decline was accompanied by a gradual, coherent evolution of public discourse, consistent with Coombs' (2023) Situational Crisis Communication Theory.

Initially, after the 2023 championship, communication was bolstering, centered on collective pride, symbolic capital, and educational values. As results declined, the discourse shifted toward diminishment, framing setbacks through contextual explanations — injuries, refereeing, or limited financial resources — while maintaining optimism and perseverance. In the final phase, surrounding Hagi's retirement as coach, communication turned toward rebuilding, emphasizing moral values, gratitude, and the long-term legacy of the "Farul–Academia Hagi" project.

In response to the first research question, the crisis was managed through shared responsibility, with Hagi contextualizing difficulties rather than personalizing failure — an approach aligned with the diminishment posture. Regarding the second question, both Hagi and the club used a hybrid strategy, combining rational explanation with emotional appeal. The club's communication remained visually consistent — blue-and-white imagery and slogans like "Mandatory Forward*!*" — reinforcing identity and stability.

Overall, the findings show that Farul Constanța and Gheorghe Hagi maintained public trust through emotional authenticity and symbolic coherence, reframing sporting decline as an opportunity for identity reaffirmation. While the club's tone remained cautious, the Hagi brand acted as the core stabilizing and legitimizing force throughout the leadership transition.

AUTHOR CONTRIBUTIONS

The article is the result of a collaborative effort in which each author contributed according to their specific expertise. The research was conducted under the scientific coordination of the second author, who supervised the conceptual framework and ensured the methodological rigor of the study. The first author was responsible for designing the research, collecting and analyzing the data, and drafting the manuscript. The third author contributed to the section dedicated to personal branding and strategic storytelling, offering interpretative insights into Gheorghe Hagi's public discourse and autobiography. The fourth author assisted in synthesizing the findings and refining the structure and language of the final version. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial or personal interests that could have appeared to influence the work reported in this paper.

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BALANCE-ORIENTED INTERVENTION IN CHILDREN WITH AUTISM SPECTRUM DISORDER: A PRE-POST CLINICAL STUDY

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ABSTRACT. *Objective***.** This paper investigates the effect of two classes of interventions (balance exercises and motor/obstacle-course activities) on balance in children with autism spectrum disorder (ASD). *Method***.** Six children (ages 6–14) diagnosed with ASD attended, between 10/01/2023 and the present, one weekly physiotherapy session (~60 min), alternating balance exercises with motor obstacle courses. Baseline and post-intervention assessments included: a Motor Assessment Form (30 items, Yes/No), the BOT-2 Balance subtest (9 items; total score 0–37), the Flamingo test (number of attempts to maintain 60 s on one leg), and a Proactive Balance Assessment (7 tasks rated "with assistance" M.A. vs. "without assistance" M.F.A.). *Results***.** All participants improved. The number of "Yes" responses on the Motor Form increased and "No" decreased for every child. BOT-2 scores rose (two children reached 37/37 at post-test). On the Flamingo test, all four eligible children reduced their number of attempts (lower score = better performance). In the proactive assessment, all shifted from M.A. to M.F.A. on most/all tasks. *Conclusions***.** A structured weekly program combining balance exercises with motor obstacle courses is associated with significant improvements in static and dynamic balance in children with ASD.

Keywords: autism spectrum disorder, balance, BOT-2, Flamingo, motor obstacle courses, physiotherapy

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INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental condition marked by persistent difficulties in social communication and interaction, alongside restricted interests and repetitive behaviors (Hodges et al., 2020). Onset typically occurs in the first years of life, underscoring the importance of timely screening and intervention to support developmental outcomes (Wang et al., 2023). Global estimates place point prevalence near 0.76%, and reliable diagnostic determinations are feasible by 18–24 months (Baxter et al., 2015; Zeidan et al., 2022).

Neurobiological findings implicate distributed brain systems rather than a single locus of dysfunction. Differences have been reported across prefrontal and temporal cortices, limbic structures such as the amygdala, and the cerebellum and hippocampus (Sauer et al., 2021), with classic observations of hypoplasia in central lobules of the cerebellar vermis (Donovan & Basson, 2017). Imaging work further suggests atypical growth trajectories an accelerated early expansion followed by relative deceleration in later childhood affecting frontal and temporal regions and the amygdala in at least a subset of children (Beopoulos et al., 2022; Askham, 2020).

Mechanistically, ASD is often framed as a disorder of neural connectivity and synaptic function arising from the interplay of genetic and environmental influences (Hodges et al., 2020; Styles et al., 2020). Beyond the defining social–communication features, motor difficulties are common and clinically meaningful estimates suggest that roughly half to three quarters of children present with clumsiness, poor coordination, and postural instability (Bhat, 2020; Kaur et al., 2018; Licari et al., 2020; Odeh et al., 2020). Given that postural control underpins daily functioning and participation, balance represents a pragmatic and high-value target in pediatric intervention.

In this context, the present study examines whether a structured weekly program integrating balance exercises with progressive motor obstacle courses is associated with gains in static and dynamic balance among children with ASD. A complementary aim is to evaluate the feasibility and clinical utility of tailoring the therapeutic plan to each child's characteristics.

Theoretical background

Physiology and neuroanatomy in ASD

Across neuroimaging and developmental studies, ASD is linked to atypical anatomy and function in large-scale networks that include the insula, anterior cingulate/medial prefrontal cortex, and nodes of the default-mode, sensory, and motor systems (Guo et al., 2024; Weber et al., 2024). Building on classic reports of cerebellar vermis abnormalities (Donovan & Basson, 2017), newer genetic imaging work associates higher polygenic susceptibility for ASD with volumetric differences in cerebellar and brainstem regions, underscoring cerebellar contributions to cognition and social behavior (Mohammad et al., 2024; Lu et al., 2023). Longitudinal infant MRI further suggests disorder relevant timing: infants later diagnosed with ASD show accelerated amygdala growth beginning between 6 and 12 months, which relates to social deficits at 24 months pointing to early emerging subcortical trajectories that precede overt symptoms (Shen et al., 2022; NIH, 2022).

Pathology, prevalence, and diagnosis

Network-level accounts characterize ASD as a disorder of connectivity and communication across cortical–subcortical circuits; recent work shows reduced “connectivity diversity,” particularly in paralimbic and heteromodal association systems, consistent with long-range underconnectivity and altered hub organization (Guo et al., 2024; Weber et al., 2024). In epidemiology, the WHO’s 2023 fact sheet estimates ASD affects about 1 in 100 children globally (WHO, 2023), while U.S. surveillance data from CDC’s ADDM Network for surveillance year 2022 report a prevalence of 32.2 per 1,000 (≈1 in 31) among 8-year-olds across 16 sites, with a ~3.4-fold higher rate in boys than girls and increases versus 2020 at most sites (CDC, 2025). Although diagnosis remains behavioral, progress on scalable biomarkers is notable: eye-tracking measures of social visual engagement (16–30 months) showed clinician-level diagnostic performance in specialty settings (Jones et al., 2023), and a 2024 primary-care study found that combining eye-tracking indices with pediatrician ratings improved sensitivity and specificity, potentially shortening time-to-diagnosis (Keehn et al., 2024).

Motor deficits and balance

Motor differences including clumsiness, coordination difficulties, and postural instability are common in ASD and have functional impact on participation (Bhat, 2020; Licari et al., 2020; Kaur et al., 2018; Odeh et al., 2020). Balance relies on multisensory integration (visual, vestibular, proprioceptive); foundational human posture research demonstrates how these channels jointly govern upright stance and how disruptions can degrade stability principles relevant to ASD motor phenotypes (Maurer et al., 2006). In the last five years, evidence has grown for practical assessment and intervention: a 2024 systematic review concluded that targeted balance-control interventions (e.g., task-specific balance training, structured play, multisensory activities) generally improve postural outcomes in ASD (Date et al., 2024), while a 2024 reliability study showed that common field tests of static and dynamic balance (including Flamingo, modified BESS, beam walking) can be administered with acceptable between-session reliability in primary school-aged autistic children useful for tracking change in clinics and schools (Baldwin et al., 2024).

MATERIAL AND METHODS

Pre–post clinical study (no control group) conducted in a private practice in Cluj-Napoca, 10/01/2023–30/06/2025. Frequency: 1 session/week, ~60 minutes/session.

Participants

N = 6 children (ages 6–14) with an ASD diagnosis. Interventions were delivered by a physiotherapist.

Procedure

Mixed program: balance exercises (e.g., stance on unstable surfaces, walking on a balance beam, controlled squats, BOSU tasks) and progressive motor obstacle courses (14 sample courses described in the source material), targeting static/dynamic balance, coordination, and postural control. Sessions included a warm-up (treadmill, bicycle, stepper).

Materials

- **Motor Assessment Form for children**
  The form includes 30 balance-related items and was used for both the initial and final assessments. Each item was scored dichotomously (“yes” or “no”), with “yes” indicating successful task completion and “no” indicating failure. The assessed tasks included activities such as turning while walking, stepping over or around obstacles, walking on uneven surfaces, riding a bicycle, or standing on one leg for 3–6 seconds.
- **BOT-2—Balance subtest**
  Assesses gross and fine motor skills in individuals aged 4–21 years and is widely used to evaluate motor competence in children with autism. The short form requires 15–20 minutes, while the complete version takes 45–60 minutes to administer (Baharudin, Harun, & Kadar, 2020).

BOT-2 includes 53 items grouped into eight subtests, with progressively increasing difficulty. In this study, only the balance subtest was administered, consisting of nine tasks evaluating static and dynamic balance under different conditions (e.g., standing or walking on a line or balance beam, with eyes open or closed). Each task was scored from 0 to 4 points based on performance time or number of steps. A second trial was conducted only if the maximum score was not achieved on the first attempt. The maximum total score for the balance subtest was 37 points.

- **Flamingo test (Eurofit)**
The Flamingo Test, part of the Eurofit test battery, assesses static and overall body balance by measuring the ability to maintain single-leg stance (Chand, Dusabeyezu, van Niekerk, & Magtibay, 2025). It is widely used in children and adults and serves as a practical tool for monitoring balance during therapeutic, educational, or sports interventions.
The participant stands barefoot on a balance beam in the flamingo position for one minute. Timing is paused after each loss of balance and resumed once balance is restored. The final score represents the number of attempts required to complete one minute. Scores of 16–25 indicate poor balance, 9–15 good balance, and fewer than 9 very good balance.
- **Proactive Balance Assessment** (7 tasks: balance board rocking, walking on a line/bench, over obstacles, course, climbing/descending stall bars, trampoline jumps), rated M.A. = “with assistance” / M.F.A. = “without assistance” (Țicărat & Ciobanu, 2012).

Data analysis

Baseline evaluation prior to the program and re-evaluation after the intervention period. Descriptive analysis of scores (baseline–post comparison) at the participant level.

RESULTS

The findings of this pre–post clinical study indicate a clear improvement in motor and balance abilities among participating children with ASD following the physiotherapy-based balance program. Statistical analyses across multiple measures consistently support the effectiveness of the intervention.

Motor Assessment Form

The number of positive ("Yes") responses increased significantly from baseline to post-intervention (*$t(5) = -10.24$, $p < .001$*), indicating enhanced performance across a broad range of motor tasks. Table 1.

Table 1. Baseline and post-intervention results on the Motor Assessment Form (number of "Yes" items)

	Std. Deviation	**t**	**df**	**Sig. (2-tailed)**
Yes (baseline) - Yes (post)	3.34664	-10.247	5	.000

Correspondingly, the number of "No" responses decreased significantly (*$t(5) = 10.25$, $p < .001$*), suggesting a meaningful overall improvement in functional motor abilities after the program. These changes reflect better coordination, body control, and execution of motor activities in daily and therapeutic contexts Tabel 2.

Table 2. Baseline and post-intervention results on the Motor Assessment Form (number of "No" items)

	Std. Deviation	**t**	**df**	**Sig. (2-tailed)**
No (baseline) - No (post)	3.34664	10.247	5	.000

BOT-2 Balance Subtest

Scores on the BOT-2 balance subtest improved significantly across all participants (*$t(5) = -15.06$, $p < .001$*), with two children achieving the maximum possible score. This finding demonstrates substantial progress in both static and dynamic balance control. The BOT-2 results are consistent with the observed improvements on other measures, confirming the positive impact of targeted balance training within the program Tabel 3.

Table 3. BOT-2 results (two trials/administrations), baseline vs. post

	Std. Deviation	**t**	**df**	**Sig. (2-tailed)**
BOT Trial 2 (baseline) - BOT Trial 2 (post)	1.87083	-15.057	5	.000

Flamingo Test (Eurofit)

Among the four participants who were able to perform the test, the number of attempts required to maintain balance for 60 seconds decreased significantly (*t(3) = 7.55, p = .005*). This improvement reflects a better ability to stabilize the body in a single-leg stance, an important indicator of postural control and neuromotor coordination. The two younger children who could not complete the test likely required developmental adaptations to appropriately assess balance at their age Tabel 4.

Tabel 4. Flamingo Test (Eurofit) results

	Std. Deviation	t	df	Sig. (2-tailed)
Flamingo baseline - Flamingo post	1.25831	7.550	3	.005

Proactive Balance Assessment

Descriptive results from this measure further support the quantitative findings. For G.N., S.C., S.T., A.M., Ș.G., and N.B., there was a predominant transitioned from performing tasks *with assistance (M.A.)* to *without assistance (M.F.A.)* across the majority of balance and coordination exercises (e.g., balance board, obstacle course, trampoline jumps). This qualitative shift reflects increased confidence, independence, and functional balance control in dynamic movement contexts.

Together, these findings provide strong evidence that a structured, mixed physiotherapy program emphasizing balance and coordination can produce measurable improvements in children with ASD, even over a relatively short period (weekly sessions since October 2023). The consistent pattern of significant gains across multiple standardized tools supports the clinical relevance of this intervention. Improvements in both quantitative and qualitative indicators suggest enhanced postural stability, motor planning, and adaptive control key developmental domains often affected in ASD.

DISCUSSION

The results of this study demonstrate that a structured physiotherapy program focused on balance, coordination, and postural control can lead to significant improvements in children with Autism Spectrum Disorder (ASD). The consistent gains observed across multiple standardized measures **Motor Assessment Form, BOT-2 Balance Subtest, Flamingo Test,** and **Proactive Balance Assessment** highlight the program's effectiveness in enhancing both static and dynamic balance, as well as overall motor function.

Our pre–post analysis showed consistent gains in static and dynamic balance after a structured weekly program that combined targeted balance drills with progressively challenging motor obstacle courses. Improvements on standardized outcomes higher BOT-2 balance scores and fewer Flamingo attempts align with recent syntheses reporting measurable benefits from postural-control–oriented interventions in autistic children, while also noting heterogeneity in protocols and limited follow-up (Date et al., 2024; Roșca et al., 2022). In our cohort, the shift on the proactive balance tasks from "movement with assistance" to "movement without assistance" reflects not only motor progress but also growing autonomy and task confidence, which is a central goal of task-oriented pediatric rehabilitation.

Reviews emphasize that multi-week, task-specific practice is associated with clearer gains in postural control, though optimal dosing remains under investigation (Date et al., 2024). Beyond conventional balance drills, technology-assisted training is accumulating supportive evidence: randomized trials of immersive/interactive virtual reality report improvements in center-of-pressure stability and motor function over short, focused programs, suggesting an engaging, feedback-rich complement to usual physiotherapy (Falivene et al., 2025; Ghafar et al., 2025). These findings are consistent with our observation that varied practice and progressive challenge features common to motor learning paradigms track with improved performance on clinic-friendly measures.

Human balance depends on efficient integration and reweighting of visual, vestibular, and proprioceptive inputs (Maurer et al., 2006). Contemporary studies in autistic samples point to central integration differences rather than uniform peripheral vestibular deficits: preschool to adolescent cohorts often show reduced stability especially when visual cues are altered or removed despite largely typical peripheral vestibular findings (Fears et al., 2023; Chisari et al., 2024). Our program deliberately manipulated base of support, surface compliance, visual conditions, and head/segment orientation, thereby taxing reweighting processes that likely underpin the observed improvements. Converging evidence from sensory-integration training adds that structured multisensory tasks can boost both balance and executive functions, with neuroimaging (fNIRS) hints of enhanced prefrontal engagement, consistent with better top-down regulation during postural tasks (Deng et al., 2023).

Motor obstacle courses embed balance in goal directed, rule based sequences (stepping over/around, narrow base walking, compliant surfaces), approximating real-world mobility challenges. This ecological emphasis is increasingly visible in clinical research, including a registered randomized trial of a standardized walking obstacle course for children with ASD (NCT06943274).

Our weekly format alternating isolated balance drills with progressively harder circuits was designed to facilitate transfer to daily activities (e.g., navigating uneven terrain, pivoting, dual-task mobility).

Using the BOT-2 balance subtest together with Flamingo is consistent with pediatric practice; recent data show that several field-based balance tests (e.g., beam/tandem walking, modified BESS) reach acceptable between-session reliability in primary-school autistic children, supporting their use for progress monitoring in clinics and schools (Baldwin et al., 2024). Where feasible, augmenting checklists and timed/score-based tasks with instrumented measures (e.g., force-plate center-of-pressure features) can increase sensitivity to change, as shown in clinic-based balance programs (Roșca et al., 2022).

Taken together, current evidence and our findings support multi-component, play-based balance programs that:

1. run for several weeks with progressive overload of postural demands;
2. systematically manipulate sensory conditions (eyes open/closed, visual flow, compliant/unstable surfaces) to train reweighting;
3. embed balance within ecologically valid, structured tasks (obstacle circuits) to drive generalization; and
4. consider VR/exergaming as an adjunct to enhance engagement and real-time feedback. These elements align with the neurodevelopmental profile of ASD and may also support executive and participation outcomes.

Limitations and future directions

This real-world study lacked a concurrent control group and involved a modest sample, limiting causal inference and generalizability limitations common to the field (Date et al., 2024). Future work should use controlled designs with longer follow-up, stratify by age, cognitive profile, and co-occurring conditions, and adopt standardized outcome batteries (including instrumented metrics) to refine dose–response and identify moderators of benefit. Ongoing and planned RCTs of obstacle-course paradigms and VR-augmented balance training will help specify who benefits most and at what dose.

Clinical implications

- Combined programs (balance + obstacle courses) can be integrated into routine therapy for children with ASD.
- Individualization by level and sensory profile is essential.
- Standardized assessments (BOT-2, Flamingo) can finely monitor progress and guide difficulty progressions.

CONCLUSIONS

This study provides preliminary but compelling evidence that a structured, physiotherapist-led balance training program can significantly improve motor and postural control abilities in children with Autism Spectrum Disorder. Statistically significant gains across all assessment tools, combined with observed qualitative progress, indicate enhanced static and dynamic balance, coordination, and functional independence.

These findings underscore the importance of individualized, engaging, and progressive physiotherapy interventions in supporting motor development in children with ASD. Continued research with larger cohorts and controlled designs is recommended to confirm these effects and refine best-practice guidelines for clinical implementation.

Limitations and Future Directions

Although the present findings are encouraging, several limitations should be noted. The study involved a **small sample size (N = 6)** and lacked a **control group**, which limits the ability to generalize results and attribute improvements solely to the intervention. Additionally, the relatively short intervention period and ongoing nature of the program make it difficult to assess the long-term sustainability of the observed gains. Two younger participants were unable to complete the Flamingo Test, indicating the need for more **age-appropriate assessment tools** in future research.

Subsequent studies should aim to include **larger and more diverse samples**, incorporate **control or comparison groups**, and perform **follow-up evaluations** to determine whether the motor and balance improvements are maintained over time. Exploring the **neurophysiological mechanisms** underlying these changes, as well as the potential effects on daily functioning, social participation, and cognitive outcomes, would also strengthen the evidence base for physiotherapy interventions in children with ASD.

AUTHOR CONTRIBUTIONS
All the authors contributed equally to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST
There are no conflicts of interest to declare concerning this study

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INTEGRATING DIGITAL TECHNOLOGIES IN OPTIMIZING PHYSICAL TRAINING FOR U18 HANDBALL PLAYERS

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ABSTRACT. *Introduction:* In contemporary sports, the integration of digital technologies into physical training has become increasingly relevant, particularly for youth athletes who are in sensitive stages of physical and functional development. For U18 handball players, the balance between maximizing performance and ensuring safe progression is crucial, making technology a valuable support for coaches and athletes. *Objective*: The purpose of this research was to analyse the effects of integrating digital monitoring tools into the physical preparation of U18 handball players. The hypothesis was that technology-assisted training would generate superior improvements compared to traditional approaches by enabling individualized workloads, objective feedback, and improved injury prevention strategies. *Material and Methods*: The study design included a sample of U18 handball players, divided into an experimental group trained with digital tools and a control group trained using conventional methods. Training was carried out over a full competitive cycle. Both groups were evaluated at baseline and after the intervention through standardized motor tests (strength, speed, agility, endurance, mobility) and physiological indicators such as heart rate (HR), heart rate variability (HRV), and accelerometery. Tools employed included GPS trackers for movement and load assessment, video analysis for technique evaluation, and sensor-based devices to measure landing forces and postural stability. *Results:* The experimental group showed faster and more consistent improvements in explosive strength, acceleration, and endurance, while also maintaining higher levels of recovery quality as

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measured through HRV. Digital feedback promoted greater motivation and awareness among athletes, while objective monitoring allowed coaches to adjust workloads more precisely, reducing signs of overload. In contrast, the control group demonstrated progress, but with higher variability and limited individualization. *Discussion*: The results supported previous literature that highlighted the benefits of integrating digital monitoring tools into sports training. The added value lay in the objectivity of data collection and the capacity to design personalized programs while minimizing injury risk. *Conclusions:* The integration of digital technologies into the physical preparation of U18 handball players proved to be more effective than traditional approaches, supporting both performance enhancement and safe athletic development. This hybrid training model represents a methodological innovation and a practical necessity in the cultivation of future elite athletes.

Keywords: digital technologies; physical training; handball; performance monitoring; injury prevention.

INTRODUCTION

Physical preparation represents one of the essential pillars of performance in team sports, and handball is among the disciplines with the most complex physical demands. Characterized by intermittent high-intensity efforts, rapid changes of direction, intense physical contact, and frequent alternations between sprint actions and active recovery, handball simultaneously requires high levels of strength, speed, agility, endurance, and coordination (Michalsik & Aagaard, 2015; Wagner et al., 2014). Match-analysis studies have shown that elite female handball players perform numerous accelerations, decelerations, jumps, and high-speed runs throughout a game, highlighting the multifactorial nature of physical performance in this sport (Póvoas et al., 2012).

For the Junior I category (female athletes aged between 16 and 18), these physical demands coincide with a critical stage of biological maturation and motor development. During this period, neuromuscular adaptations, coordination refinement, and strength development are still ongoing, making the systematic evaluation and optimization of physical preparation decisive for long-term athletic development and future performance at the senior level (Lloyd & Oliver, 2012; Myer et al., 2011).

Traditional assessment methods, such as manual timing, visual observation, or subjective evaluation of effort, offer limited accuracy and often fail to capture the true external and internal load experienced by the athlete (Impellizzeri et al., 2005). In the context of increasing digitalization in sport, modern monitoring technologies, particularly Global Positioning System (GPS) devices combined with inertial sensors, have become indispensable tools in performance analysis. These systems allow real-time and post-session monitoring of key movement parameters, including maximum and average speed, frequency and intensity of accelerations and decelerations, total and high-intensity distance covered, neuromuscular load (PlayerLoad), as well as multidirectional movements and ground impact forces (Cummins et al., 2013; Akenhead & Nassis, 2016).

By correlating GPS-derived data with the results of standardized physical tests, coaches and sports scientists can obtain a more comprehensive and objective assessment of physical preparation, identify individual strengths and weaknesses, and personalize training interventions accordingly (Buchheit & Simpson, 2017). Moreover, the integration of GPS technology into the testing process of Junior I handball players offers multiple advantages, including increased measurement precision through the reduction of human error, contextual interpretation of test performance by comparison with match demands, longitudinal monitoring across the competitive season, and injury risk reduction through early detection of neuromuscular overload or movement asymmetries (Gabbett, 2016; Malone et al., 2017).

Therefore, the present study aims to highlight the usefulness of integrating sports GPS technology into six standardized physical assessment tests (Countermovement Jump, 10–20 m Sprint, T-Test, Yo-Yo Intermittent Recovery Test Level 1, Y-Balance Test, and Landing Error Scoring System), in order to demonstrate the positive impact of digitalization on the objectivity, accuracy, and practical relevance of the data obtained within the training process of Junior I female handball players.

MATERIAL AND METHODS

Participants

The study was conducted on **20 Junior I female handball players**, aged between 16 and 18 years, registered with handball clubs and engaged in competitive preparation. The selection of this sample was justified by the fact that at this age athletes are in a transition stage towards senior-level performance, and optimizing physical preparation has a direct impact on future performance. Inclusion criteria required regular participation in training (minimum three sessions per week), absence of severe injuries in the past six months, and the consent of both athletes and their coaches for participation. The study was approved by the Ethics Committee, and informed consent was obtained from all participants prior to testing.

Equipment and technologies used

A Catapult Vector S7 sports GPS system or equivalent was employed, equipped with a triaxial sensor (accelerometer, gyroscope, and magnetometer) and a recording frequency ranging between 10 and 18 Hz. Monitoring was carried out using a special vest that fixed the GPS unit in the dorsal area without interfering with movement biomechanics. Data were downloaded and processed using Catapult OpenField software or equivalent. Auxiliary materials included manual stopwatches, measuring tapes, cones, and testing areas marked in accordance with standardized protocols.

Fig. 1. Catapult Vest
(CATAPULT, n.d.)

Applied tests

The testing battery included six standardized physical assessment protocols. The Countermovement Jump (CMJ) was performed through three maximal jumps by each athlete, with 30-second rest intervals between attempts. GPS parameters analysed included vertical acceleration, impulse force, and jump consistency, which are relevant to lower limb explosiveness. The 10–20 m Sprint involved starting from a static position and running distances of 10 and 20 m, measured through both traditional timing and GPS recording. The parameters analysed were maximum speed, initial acceleration, and deceleration at stopping, relevant for short-distance acceleration and speed, typical in handball.

The T-Test for agility consisted of running a T-shaped route, including forward, lateral, and backward movements. GPS recorded multidirectional accelerations and decelerations, as well as neuromuscular load (PlayerLoad), indicators relevant to agility and the ability to change direction rapidly. The Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) involved repeated 20 m runs with 10-second recovery intervals until exhaustion. Parameters analysed included total distance covered, number of sprints, and effort intensity, relevant for intermittent endurance and recovery capacity.

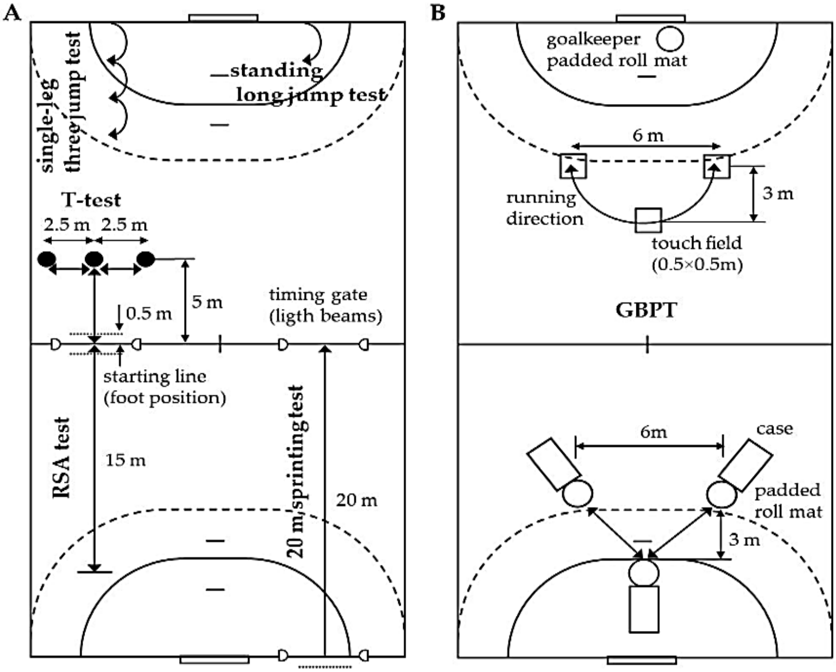

Fig. 2. Battery tests
(Wagner & Hinz, 2023)

The Y-Balance Test required the athlete to maintain balance on one leg while performing reach movements in anterior, posteromedial, and posterolateral directions. GPS recorded accelerometer variations and postural deviations, providing information about functional balance and injury risk. Finally, the Landing Error Scoring System (LESS) involved jumping off a low platform followed by ground landing, with motion recording. Parameters analysed included vertical impact force, lateral accelerations, and PlayerLoad upon landing, indicators relevant to the identification of landing technique deficiencies and the risk of knee and ankle injuries.

Fig. 3. Illinois Agility Test
(Reyes, 2023)

Data collection procedure

The tests were administered in a single session following a standardized 15-minute warm-up. The order of application was: CMJ, Sprint, T-Test, Yo-Yo IR1, Y-Balance, and LESS. The GPS system was activated before the session began and data were downloaded immediately after completion. Each test was performed at least twice, whenever the protocol allowed, to ensure reliability of the results.

Data analysis

Traditional data obtained through manual timing and visual observation were compared with GPS-derived data. The main indicators analysed included maximum speed, accelerations and decelerations, neuromuscular load (PlayerLoad), total distance covered, jump consistency, and balance deviations. Results were reported both individually and collectively in order to highlight overall performance as well as the specific characteristics of each athlete.

All data were processed using descriptive and inferential statistical methods. Descriptive statistics included the calculation of means, standard deviations, minimum and maximum values for all measured variables. Data normality was assessed using the Shapiro–Wilk test. Depending on data distribution, paired-sample t-tests or Wilcoxon signed-rank tests were applied to compare traditional assessment results with GPS-derived measurements.

The relationships between variables were examined using Pearson's or Spearman's correlation coefficients, as appropriate. Effect sizes were calculated to determine the magnitude of observed differences. The level of statistical significance was set at $p < 0.05$.

RESULTS

The application of the six physical tests provided a comprehensive evaluation of the physical preparation level of Junior I female handball players. The integration of GPS technology enabled a more objective and detailed analysis of performance compared to traditional assessment methods.

In the Countermovement Jump (CMJ) test, the mean jump height assessed through classical measurement was **32.4 ± 4.1 cm**. GPS-derived data revealed a mean peak vertical acceleration of **2.85 ± 0.37 g** and a mean PlayerLoad per jump of **0.42 ± 0.06 AU**. Although several athletes presented similar jump heights, GPS analysis identified notable differences in movement consistency, with coefficients of variation ranging from **4.8% to 11.6%** across repeated trials.

For the 10–20 m Sprint test, the average sprint time recorded using manual timing was **3.41 ± 0.18 s**, while GPS analysis indicated a mean maximum speed of **6.72 ± 0.54 $m \cdot s^{-1}$**. Acceleration profiles showed that **35% of the athletes** achieved peak acceleration within the first 10 m but demonstrated a reduction in speed during the final segment, whereas others maintained a more uniform speed profile throughout the sprint distance.

In the T-Test, the mean completion time measured using traditional methods was **10.12 ± 0.63 s**. GPS data recorded a mean total PlayerLoad of **6.84 ± 1.12 AU**, with high inter-individual variability. Athletes with faster completion times exhibited significantly higher deceleration loads ($p < 0.05$), suggesting increased biomechanical stress despite superior performance outcomes.

During the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1), the average total distance covered until exhaustion was **1240 ± 280 m**. GPS analysis revealed a mean of **42.6 ± 8.3 high-intensity runs** and a cumulative PlayerLoad of **312 ± 54 AU**. Notably, athletes who covered comparable distances displayed differences of up to **18%** in total neuromuscular load, indicating varying levels of movement efficiency.

In the Y-Balance Test, traditional measurements indicated anterior reach distances of **93.1 ± 6.4%**, **95.7 ± 5.8%**, and **94.3 ± 6.1%** of limb length for the three reach directions. GPS analysis identified center-of-mass deviations exceeding **3.5 cm** in **25% of the athletes**, revealing postural instabilities that were not evident through visual assessment alone.

In the Landing Error Scoring System (LESS), the mean visual score was **4.6 ± 1.3 points**, indicating acceptable landing technique. However, GPS-derived impact data showed peak vertical ground reaction proxies exceeding **5.2 ± 0.7 g** in **30% of the athletes**, suggesting elevated knee joint loading despite favorable visual scores.

Overall, the comparison between traditional and GPS-based assessment methods demonstrated that classical testing provides a general overview of physical performance, while GPS integration allows for a more precise evaluation of biomechanical load, movement quality, and injury-related risk factors. This combined approach enables a multidimensional assessment of athletes, extending beyond basic performance indicators such as time, distance, or jump height.

DISCUSSION

The results obtained from the applied tests confirm that the use of digital technologies, particularly sports GPS systems, provides a significant advantage in the evaluation of Junior I female handball players. Similar findings have been reported in the literature, where GPS-based monitoring has been shown to offer a more comprehensive representation of external load and movement demands compared to traditional assessment methods (Cummins et al., 2013; Akenhead & Nassis, 2016). While classical tests provide essential indicators such as time, distance, or visual scores, GPS technology introduces additional dimensions of interpretation, including accelerations, neuromuscular load (PlayerLoad), effort distribution, and movement quality.

The relevance of these findings for handball is evident, as the sport is characterized by intermittent high-intensity efforts, rapid changes of direction, and complex biomechanical demands. Previous match-analysis studies in female handball players have demonstrated a high frequency of short sprints, accelerations, decelerations, and jumping actions during competition, which are insufficiently captured by traditional evaluation alone (Michalsik & Aagaard, 2015; Póvoas et al., 2012). The present study supports these observations, showing that GPS monitoring allows a more detailed analysis of such sport-specific actions.

An important contribution of GPS technology, also highlighted in previous research, is its capacity to identify inter-individual differences among athletes with similar classical performance outcomes. Buchheit and Simpson (2017) emphasized that athletes with comparable sprint times or distances covered may exhibit substantially different acceleration profiles and mechanical loads. The results of the present study align with these findings, demonstrating that athletes achieving similar sprint performances differed in acceleration efficiency and neuromuscular load, with direct implications for individualized training prescription.

In terms of injury prevention, the present findings are consistent with studies indicating that excessive cumulative load, high deceleration demands, and repetitive impact forces are associated with an increased risk of injury in team sports (Gabbett, 2016; Malone et al., 2017). While traditional methods often fail to detect these risk factors, GPS combined with inertial sensors enables the identification of potentially harmful movement patterns, such as elevated landing impacts or asymmetrical loading, allowing for early preventive interventions.

Another advantage of GPS technology highlighted both in this study and in the literature is the possibility of continuous performance monitoring. Unlike classical testing, which provides isolated assessments at specific time points, GPS allows longitudinal tracking of workload and recovery across training sessions and matches (Impellizzeri et al., 2019). This approach supports better-informed decisions regarding training load management and recovery strategies, particularly in developing athletes.

Despite these advantages, the integration of GPS technology into the training process presents certain challenges. As noted by Bourdon et al. (2017), data interpretation requires specific expertise, and the information obtained must be carefully contextualized within the technical and tactical demands of the sport. Nevertheless, the consistency between the present results and those reported in the literature suggests that the benefits of GPS monitoring in terms of assessment accuracy, individualization, and injury prevention justify its implementation.

Overall, the discussion highlights that the transition from traditional to digital evaluation should not be viewed as a complete replacement of classical methods, but rather as a complementary approach. Traditional tests remain valuable due to their simplicity and accessibility, while GPS technology enhances scientific rigor through objective and multidimensional analysis.

In conclusion, when compared with existing literature, the findings of the present study reinforce the role of GPS technology in improving the physical assessment of Junior I female handball players. The integration of digital monitoring systems contributes to a deeper understanding of individual performance characteristics, a more precise evaluation of movement quality, improved injury prevention strategies, and the development of personalized training programs, thereby supporting long-term athlete development.

CONCLUSIONS

Specific physical preparation in handball for Junior I players proved essential for the development of sports performance, as strength, speed, agility, and endurance parameters influence the transition to senior-level competition. Classical evaluation methods provided a general overview, but they were limited by subjectivity and the lack of biomechanical detail. The integration of digital technologies, such as GPS systems, allowed for an objective and detailed analysis of performance, highlighting significant differences in execution and efficiency even among athletes with similar results obtained through traditional methods. The applied tests covered fundamental physical components for handball: explosiveness, speed, agility, endurance, balance, and biomechanical safety, thus providing a comprehensive tool for optimizing training and preventing injuries.

The integration of GPS technology into the evaluation of Junior I players should complement classical methods, offering coaches a more comprehensive view of athlete performance and allowing for the personalization of training programs according to individual needs, such as adjusting sprint or stability exercises. Monitoring parameters such as PlayerLoad and landing forces contributes to injury prevention through mobility programs, proprioceptive exercises, and corrective techniques. Periodic evaluations, for example on a quarterly basis, allow for tracking progress and adjusting preparation strategies. Furthermore, the integration of GPS technologies in educational and scientific contexts supports coach education and enhances the professional level in youth sport.

AUTHOR CONTRIBUTIONS

Ms. student PhD. Roxana-Nicoleta POPA, Mr. student PhD. Alex-Paul SECIU, Mr Prof. PhD. Virgil ENE-VOICULESCU and Ms Prof. PhD. Carmen ENE-VOICULESCU contributed in equal measure to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this doctoral report.

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STANDARDIZATION OF EFFORT PARAMETERS IN ACCORDANCE WITH THE PHYSIOLOGICAL CHARACTERISTICS OF WOMEN APPLIED IN HANDBALL. A SYSTEMATIC REVIEW

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ABSTRACT. *Introduction***:** Female handball is an intermittent sport with heavy physical contacts that requires alternating high-intensity actions over short periods of time with low-intensity actions. Resistance training improves muscular endurance, muscular strength, power, velocity and agility. Performing sport-specific motor skills with high values of these qualities in handball influences the final result. During a general resistance exercise performed at moderate to high intensity, women oxidize more fat and less carbohydrates compared with men at the same relative intensity. For this reason, women will have a lower level of muscle fatigue. *Purpose***:** Standardization of volume and intensity to the female particularities and handball specific motor skills. *Research methods***:** The PRISMA diagram was used to determine the studies that met the inclusion criteria for systematic analysis. A total of 363 female who play handball were included. *Results:* Women can perform more repetitions compared with men at an intensity between 40–60% of maximal strength. The best values for resistance training are reached by performing a number of 20–28 RM. *Conclusion:* A discrepancy was found between the physiological particularities of the female sex and the standardization of effort parameters in the training plans of the studies included in this analysis.

Keywords: female handball, resistance training, muscle metabolism, sport physiology.

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INTRODUCTION

The first treatise on the topic of gender differences in muscle strength was written by Quetelet (1842). Other studies followed (Carman, 1899; Metheny, 1941) with similar results regarding men's superior muscle strength. Numerous studies (Jaworowski 2002; Russ, 2005; Roepstorff, 2006; Wüst, 2008; Hunter, 2014; Nuzzo, 2023) highlight women's greater resistance to muscle fatigue. However, the importance of developing a training plan in relation to gender characteristics is not yet well elucidated. There are syntheses that include participants of both genders and generate training suggestions (Petruzela, 2023).

Jaworowski (2002) shows that women have a higher percentage of slow fibers in their muscle composition, an idea supported by a number of researchers in their studies (Russ, 2005; Roepstorff, 2006; Wüst, 2008; Hunter, 2014). Hunter (2014) also shows that women tolerate metabolic stress better than men. Although women have lower muscle mass (Cheuvront, 2005), they are more resistant to muscle fatigue (Wüst, 2008). Women's muscle blood flow is higher than that of men (Hunter, 2014). The higher density of capillaries, which is specific to type I fibers, promotes better muscle vascularization (Hunter, 2001; Hogarth, 2007; Parker, 2007). B2-adrenergic receptors are more densely located around slow fibers, stimulating vasodilation (Roatta, 2010). Blood flow provides oxygen and removes metabolic products from the muscles. Low blood flow accelerates peripheral fatigue, which interferes with contractile functions (Hunter, 2014). Platonov (2015) shows that the percentage of adipose tissue in women is approximately twice as high as in men. During moderate to high intensity resistance exercise, women oxidize more fat and fewer carbohydrates compared to men at the same relative intensity (Hunter, 2014; Horton, 1998; Carter, 2001; Roepstorff, 2006). The presence of estrogen (17-estradiol, E2) influences lipid metabolism in skeletal muscle in women (Maher, 2010). From a muscular and hormonal point of view, during moderate-to-high intensity activity, women will experience lower levels of muscle fatigue and faster recovery of strength and power compared to men (Hunter, 2014).

Several studies support the idea that women are more resistant to muscle fatigue than men. At leg press, Hoeger (1990) found that women can perform more repetitions than men at an intensity of 40-60% of maximum strength. Other studies (Maughan, 1986; Miller, 1993) show that women can perform approximately 13-16 more repetitions than men at an intensity of 60% of maximum strength. The results of studies (Hunter, 2001; Hunter, 2004) show that women can sustain isometric and isotonic muscle contractions at low to moderate intensity better than men. Some research in the literature shows that resistance training improves the body's capacity as expressed in indices of:

muscle endurance (Schoenfeld, 2015), muscle strength (Schoenfeld, 2018), power (Pareja-Blanco, 2017), speed (Contreras, 2017), and agility (Speirs, 2016). Performing specific motor skills with high indices of these qualities in handball influences the final result (Póvoas, 2012). The percentage of fiber types that compose a muscle varies depending on its tasks in the body (Baechle, 2021). The forces acting on the muscles when performing specific throwing or jumping movements are different. The intensity must be related to the combination of force and speed to which the muscles are exposed during matches. For jumping variables, the dominant component is force, because during landings, athletes withstand forces up to 4.6 times greater than their own bodyweight (Iida, 2011).

In sports games, when running, athletes apply approximately twice their body weight to the ground with each contact (Bompa, 2014). The defining element of throwing in handball is speed (Van Muijen, 1991). Resistance training, applied to women at a lower intensity, contributes to improving maximum force production (Taber, 2019). The ability to repeatedly perform these specific motor skills with high strength and speed indices throughout the match determines performance in team sports (Póvoas, 2012). Some research (Hoff, 1995; Hermassi, 2010) associates a higher level of maximum strength with a higher rate of winning duels due to high strength parameters; or with more goals scored due to high speed parameters. The primary objective of handball is to score more goals than the opposing team. Throwing speed and accuracy are essential components of an effective throwing mechanism, significantly increasing the chances of success (Granados, 2007; Sarvestan, 2019).

Throwing efficiency directly influences the final result (Ferrari, 2018) and, as noted by Karastergios (2017), serves as a distinguishing factor between winning and losing teams. Enhancing throwing velocity reduces the goalkeeper's reaction time (Bouagina, 2022), a key factor in successful goal scoring (Van den Tillaar, 2003). Prolonged flight phases optimize the decision-making time during jump shot (McGhie, 2020; Iacono, 2016). In professional handball, jump shot is used in over 70% of offensive situations, making it the most frequently employed technical skill (McGhie, 2020). Standardizing training load parameters contributes to maximizing athletic performance. Therefore, the intensity–volume ratio must be aligned with the energy systems involved and the muscle fiber composition specific to female athletes. The cumulative training effect leads to increased muscular strength and improved performance indicators. Prolonged muscular tension generates significant metabolic stress, leading to increased lactate production (da Silva, 2017; Wilk, 2021) and a reduction in oxygen availability within the active muscle (Tanimoto, 2008).

This process stimulates mitochondrial protein synthesis (Burd, 2012). Training protocols involving high repetition volumes at low-to-moderate intensity (30–60% of 1RM) promote increased capillary density and mitochondrial volume, thereby enhancing oxidative metabolism (Mang, 2022). The application of these training parameters leads to significant improvements in muscle resistance (Groennebaek, 2017; Parry, 2020). Campos (2002) concludes that the optimal range for developing muscle resistance is achieved by performing 20–28 repetitions per set.

The purpose of this review is to identify in literature, the key physiological factors that establish the design of periodization strategies adapted to the specific characteristics of female athletes and the ergogenic demands of handball.

MATERIAL AND METHODS

The 'Prisma' diagram adapted for systematic review applied in 'Sport Science' was used.

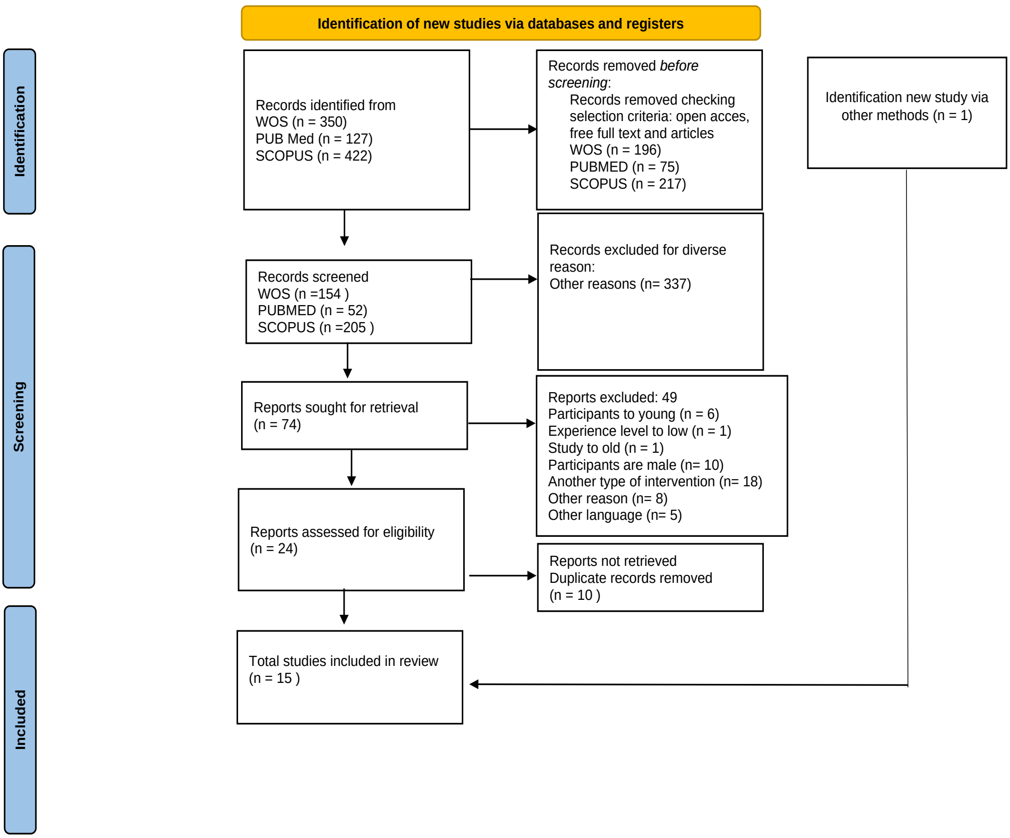

Fig. 1. Prisma Diagram

Eligibility criteria and Identification process in literature

The study framework was developed using the “PICOT” acronym. The selection process was carried out across three databases: Web of Science, Scopus, and PubMed. Adhering to the specific guidelines of each search engine, a search algorithm based on the acronym was constructed to retrieve relevant studies. Following the selection of specific fields, only studies meeting the predefined eligibility criteria were included. Studies from grey literature were not considered, and the identification process was conducted independently.

Exclusion criteria and data extraction

All studies were excluded in which participants met any of the following conditions: were male; had practiced handball for less than 2 years; or girls younger than 15 years old. Only studies that measured jump and throw variables were included in the analysis. Additionally, only articles were retained for analysis. We opted for studies published after 2010 and written in english. The final table for eligible studies was adapted to include study data (title, author, year, abstract, aim, and objective). For the intervention conducted by Chaabene (2021), the author was contacted to obtain the complete study data. The study by Fristrup (2024) was sourced from citations in other articles and was incorporated into our analysis criteria.

RESULTS

Initially, 899 articles were identified. After excluding studies that did not meet the desired criteria, 74 articles were analyzed in full-text. Due to age restrictions, 6 studies were excluded. Ten studies were excluded based on gender criteria. Eighteen studies were excluded because the interventions were not experimental, 5 were excluded for not being written in English, and 10 were excluded for various other reasons. The literature search was finalized on December 1, 2024. Only one study was included by consulting citations and reference lists of other studies. In total, 15 interventions met our criteria.

Table 1. Studies that use low intensity

Study	RT - intensity	Variable	Sig. prag	Sample
Genc (2019)	Core training	SLJ, CMJA;	SLJ (p= 0.210) CMJA = 32.54±4.02; 32.80±4.02	20 female
Raeder (2015)	Medicine ball	Throw speed 7 m	Throw speed (p = 0.001). 14% GE improve at post test	28 female
Hammami (2024)	Elastic band	SJ, CMJ, SLJ, 1RM bench, Hsquat	SJ (p=<.01) CMJ (p=<.01) SLJ (p=<.01) 1RM bench (p=<.01) HSquat (p=<.02)	30 female
Gaamouri (2023)	Elastic band	SJ, CMJ, SLJ, 1RM bench, Hsquat	SJ (p = 0.002) CMJ (p = 0.002) SLJ (p=<.01) 1RM bench (p = 0.02) HSquat (p = 0.009)	34 female
Hammami (2022)	Elastic band	SJ,CMJ, CMJA	SJ p = 0.048) CMJ p = 0.017 CMJA p = 0.019 (compared with GC)	26 female
Gaamouri (2024)	Elastic band, after 6 weeks of adaptory phase	SJ,CMJ,SLJ, 1RM BENCH, 1RM Hsquat	Sj = $p < 0.05$ Cmj = $p < 0.05$ Slj = $p < 0.05$ 1rm bench = $p < 0.05$ 1rm Hsquat = $p < 0.05$	30 female

Table 2. Characteristics of studies that use low intensity

Study	Dur/frv	Set/rep	Pause	Note	Results
Genc (2019)	8 weeks, 3/week	2x10 to 2x35	1' between ex, 3 between sets	Volume increased throughout intervention	Performance does not improve.
Raeder (2015)	6 weeks, 3/week	3x6x2kg, to 2x12x1kg	60'' to 90''	Training volume increase every 2 week, from 3x6,2x8 until 3x10,2x12, also recovery time increased from 60s to 90s	Report a throw speed improvement (14%) in GE, without affecting throwing accuracy
Hammami (2024)	8 weeks, 2/week	3x10 to 5x10 progressive, elastic elongation to 250%	30'' between sets	Volume and intensity (elastic elongation) improved in every week	Jump outcome improved (SJ,CMJ,SLJ p<.001), maximal strength also improve (bench press p<.01 and Half squat p<.02)

Study	Dur/frv	Set/rep	Pause	Note	Results
Gaamouri (2023)	10 weeks, 2/ week	3x10 to 5x10 progressive, elastic elongation 250%	30'' between sets	Volume and intensity (elastic elongation) improved in every week	improve (GE) compare to GC at SJ and CMJ p = 0.002, also maximal strength outcome improve; bench press (p = 0.02) ; and half squat (p = 0.009)
Hammami (2022)	10 weeks, 2/ week	3x10 elastic elongation at 250% to 5x10 with 16 kg.	30'' between sets	Overall, the intervention accounted for less than 10% of the total training volume.	Significant results are reported in the experimental group (EG) compared to the control group (CG) for the measured jump variables.
Gaamouri (2024)	10 weeks, 2/ week	3 x (6+6) with 3.2 and 1.8 kg to 5 x (6+6) with 16 and 8.8 kg	30'' between sets	A 6-week adaptation period was implemented: the first 3 weeks at 40–60% intensity, followed by 3 weeks at 70–85% intensity, after which the elastic band intervention was carried out.	Significant results in jump performance and maximal strength; Sj = $p < 0.05$ Cmj = $p < 0.05$ Slj = $p < 0.05$ 1rm bench = $p < 0.05$ 1rm Hsquat = $p < 0.05$

Table 3. Studies that use high intensity

Study	RT - intensity	Variable	Sig. Prag results	Sample
Slovak (2019)	Olympic weightlifting	CMJ, CMJA, 1RM squat	*CMJ* = PRE 0.29 (±0.05); POST = 0.28 (±0.05) *CMJA* = PRE 0.34 (±0.04); POST = 0.33 (±0.05) ***1RM Squat = PRE 77.02 (±5.77); POST 143.47 (±2.09)***	10 female
Saeterbakken (2011)	Core training	Throw velocity at 7 m	Pre – p= 0.364 inter group Post – CON (p= 0.418) ***EXP – (p = 0.01)***	24 female
Chaabene (2021)	Balance and complex training vs complex training only	CMJ, SLJ, HALF SQUAT 1RM	CMJ = P > .05 SLJ= P > .05 1RM Hsquat = P > .05	23 female
Orduña-Borraz (2024)	GC = normal program from club 75%, GE additional did olympic training at 20-30% from own bodyweight	CMJA, throw velocity from 7 m	CMJA = p < 0.01 Throw velocity from 7m= GC dif T1-T2(p < 0.01) GE t1-t2 (p < 0.001)	21 female

Study	**RT - intensity**	**Variable**	**Sig. Prag results**	**Sample**
Andersen (2018)	(elastic band 5-6 Borg la 7-8 Borg)	CMJ, CMJA, throw velocity from 7m	CMJ = p = 0.02 CMJA = p = 0.02 throw velocity from 7m **p = 0.07**	12 female
Sabido (2017)	Isoinertial device (kBox 3, Exxentric AB TM, Bromma, Sweden)	CMJ, 1RM Hsquat	CMJ = 70/30/0 Possibly Positive (GE) 1rm Hsquat 99/1/0 Very likely positive	18 female
Eler (2024)	GE – cluster method 80% GC – traditional method 80%	Slj, cmj, throw velocity, squat and bench press	Slj = $p < 0.05$ CMJ = $p < 0.05$ between group	32 pro female
Fristrup (2024)	8 weeks-2/week GC – usual GE – traditional (from 3x12 to 3x4)	CMJ	CMJ = (GE p=.012); GC(p= .044); compare to T1. Between group at post test *p=.463* non-significant	27 female
Sabido (2016)	Unknown intensity	Throw velocity	GE improve throw velocity (4.7%); jump shot velocity (5.3%). But improvement are not sig (p > 0.05).	28 female

Table 4. Characteristics of studies that use high intensity

Study	**RT**	**Dur/frv**	**Set/rep**	**Pause**	**Note**	**Results**
Slovak (2019)	1/ week, 4 week (TST) 2/week, 4 week	14 weeks	S1-4 = 3x10 to 4 x 3 S5-8 = 3x10 to 3 x 5	-	6 weeks of adaptation followed by 4 weeks in the preparatory phase 1 – traditional strength training, and the subsequent 4 weeks – Olympic weightlifting.	Jump variables (CMJ, CMJA) do not improve, but 1RM in the squat shows improvement.
Saeterbakken (2011)	Core stability	6 weeks / 2-week	4 x 4-6 rep(max)	1-2'	The intervention was based on abdominal muscle stability exercises. Both groups followed the standard strength training program, but additionally, the experimental group (EG) performed the stability exercises twice a week.	GE improve throw velocity, GC unchanged

Study	**RT**	**Dur/frv**	**Set/rep**	**Pause**	**Note**	**Results**
Chaabene (2021)	Combine balance with CT; vs complex training	8 weeks/ 2-week	GC – 3x8 (80%) + 3x6 to 3x12 jumps GE – idem + 3x40s balance training	90'' rest	One group did complex training, second did complex training + balance training.	Results improved in both groups, but not significantly for the throwing and jumping variables.
Orduña-Borraz (2024)	Olympic movement	GC-6 weeks/ 2-week	GC- (75% 1RM) GE – additionally from GC 3x8 rep, intensity 20%-30% with bodyweight	-	GC utilizes normal training program. GE did training program + Olympic training.	Improved CMJA, throw velocity 7m(GE), did 20-30% from bodyweight.
Andersen (2018)	Explosive elastic band	9 weeks, 3-week	3 x 10 rep at 5-6 BORG - 3x6 rep @ 7-8 on BORG	-	The intervention was applied after an 11-week control period	Throw velocity p>.05; CMJ (p = 0.02) CMJA (p = 0.02)
Sabido (2017)	isoinertial device (kBox 3, Exxentric AB TM, Bromma, Sweden)	7 weeks, 1 week	4x8 excentric	-	Both the experimental group (EG) and control group (CG) continued their usual training programs, but the EG additionally performed one eccentric training session per week for 7 weeks	Insignificant results were reported for throwing velocity, but both groups showed improvements in CMJ and 1RM half squat.
Sabido (2016)	Unknown intensity from subjects (30,50, 70%)	4 weeks 2-week	4 x 6	-	Both groups performed 4 sets of 6 repetitions, but in the control group (CG) the load was known, whereas in the experimental group (EG) the load was unknown. In the EG, the load alternated between 30%, 50%, and 70%.	GE improved throw velocity (4.7%) jump shot (5.3%). Nevertheless, the improvements are not statistically significant. (p > 0.05).

Study	RT	Dur/frv	Set/rep	Pause	Note	Results
Eler (2024)	Cluster vs traditional	6 weeks, 3 week	GC = 2 x 12 GE = 2 x (4x3)	Rest between reps just at GE =20 sec; between sets at GC = 2-3 min, at GE = 5 minutes	GC did 6 weeks 3/week, 2 x 12 rep, GE did 12 rep= 3 x 4.	Slj = $p < 0.05$ CMJ = $p < 0.05$ between groups
Fristrup (2024)	Traditional - 12 RM(70% la 4RM(92%).	8 weeks, 2/week)	GC = usual training GE – 3x 12 rep 70% 1RM, from 3 x 4 92%	1-2 min exercise; 2-3 min sets	GC usual training; GE 2/ weeks, first training, explosive strength, second (TUT).	CMJ (GE p=.012); GC(p= .044); compare to T1.

Study characteristics

Based on the outcome analyzed

The interventions included in this analysis investigated the specific throwing and jumping skills of handball. The most studied jumping procedure was the countermovement jump (10 studies). The countermovement jump with arm swing and the standing long jump were investigated in 6 studies. The vertical jump from a squat position was examined in 4 studies. The technical throwing procedures analyzed were: standing throw velocity (6 studies) and jump throw velocity from 9 meters (3 studies). Maximal strength was tested through: bench press (4 studies), half squat (5 studies), and full squat (2 studies). Substances that may enhance athletic performance (creatine, caffeine) were prohibited. Researchers allowed ad libitum water consumption.

Based on Sample Size

This literature synthesis included a total of 363 female handball players. The smallest sample consisted of 10 girls in Slovak's study (2019), while the largest included 34 participants in Gaamouri's study (2023). The number of participants was accounted after dropout. The dropout rate was less than 15% in the studies included in the analysis, except for the study by Fristrup (2024). The participants' ages ranged from 15.8 to 26.2 years. In the studies by Eler (2024) and Fristrup (2024), the girls had more than 13 years of handball experience. In the other studies, the playing history ranged between 3 and 9 years.

DISCUSSION

General Aspects

This review investigated methods for developing resistance training applied in female handball. Throwing and jumping outcome, which constitute the specific skills of handball, were analyzed. The aim of this review was to identify physiological aspects in the literature that determine the design of periodization adapted to gender-specific characteristics and the ergogenesis of the sport. From the perspective of effort parameters, there is a discrepancy between the female-specific characteristics reported in physiology studies and the training plans used in the studies included in this analysis. In this section, due to the homogeneity of the analysis, only interventions conducted on female samples will be discussed.

Effect of Resistance Training on Throwing Performance in Handball

The interventions analyzed in this synthesis measured throwing velocity from 7 meters. Significant results were obtained by researchers who applied training at low intensity percentages. Raeder (2015) used the ballistic method with medicine balls and achieved significant improvements, increasing throwing velocity by 4–14%. The training plan included various types of throws, with exercise dosage ranging from 3 sets of 6–10 repetitions using 1–2 kg medicine balls. The weightlifting method was applied by Orduña-Borraz (2024) at a low intensity (20–30% of bodyweight), yielding significant results. Dosage ranged between 2–3 sets of 6–12 repetitions. The percentage of intensity relative to bodyweight is a common method in studies conducted on women but presents practical application challenges. Andersen (2018) used rigid elastic bands (5–9 Borg RPE) and did not achieve significant improvements in throwing velocity. Eler (2024) obtained significant results after 6 weeks at an intensity of 80% 1RM using the cluster method.

There are differences in participant characteristics. The average sports history of females who achieved significant results at intensities above 70% was 15.73 years, with a mean age of 26.20 years. In low-intensity studies, the volume parameter was very low. This mode of standardizing parameters does not align with the previously presented particularities. Women are more fatigue-resistant compared to men (Wüst, 2008), have a higher proportion of slow-twitch muscle fibers (Jaworowski, 2002), and tolerate metabolic stress better than men (Hunter, 2014). Additionally, Hoeger (1990) demonstrated that women can perform a higher number of repetitions at low intensities compared to men. Campos (2002) showed that the best performances in resistance training occur within 20–28 repetitions. Petruzela (2023) recommends an intensity greater than 55% 1RM for improving throwing velocity; however, the sample was mixed. Sample heterogeneity may lead to bias due to gender differences. Saeterbakken (2011) conducted an intervention using abdominal stability exercises at an intensity ranging between 4–6RM and achieved significant improvements in throwing velocity. The role of the abdomen in throwing velocity is to absorb, add, and transfer force from the lower to the upper limbs (Kibler, 1994). Studies addressing high-volume training aimed at improving abdominal muscle strength show contradictory results (Stanton, 2004; Dale, 2005).

Effect of Resistance Training on Jump Performance in Handball

Researchers (Hammami, 2022; Gaamouri, 2023; Gaamouri, 2024; Hammami, 2024) used similar values regarding training load and plan. The elongation of elastic bands ranged between 100–250%, with intensities from 1.8 to 16 kg; the training volume consisted of 3–5 sets of 6+6 repetitions. This protocol produced significant effects on jump performance variables. Participants were aged between 15 and 16 years, with a body fat percentage ranging from 21.5% to 26.6%. In the intervention conducted by Genc (2019), jump performance did not improve following an abdominal muscle strengthening program (10–30 repetitions). Eler (2024) significantly improved vertical jump performance by applying Cluster method at an intensity of 80%. However, based on the characteristics of this method, the quantitative component was once again not fully met. These improvements may be noticeable under laboratory testing conditions, but their transferability to sport-specific performance remains questionable. Countermovement jump performance improved significantly in Fristrup (2024) study, which applied a moderate intensity (10–12 RM) using Mang's (2022) principle of long time under tension. A common characteristic of both this and Eler's study is the participants' experience level, ranging between 15.7 and 17.4 years. In Fristrup's study, the average body fat percentage ranged between 18.5% and 21.5%. Chaabene (2021) supports the direction of these significant results, applying a high intensity (80%) using the Complex Training method. The participants had a training history ranging from 7 to 9 years.

In Andersen's (2018) study, jump variables improved, while throwing velocity did not change. One of the objectives of this synthesis is to standardize intensity in relation to the targeted skill, highlighting the need for different percentages depending on the motor skill. Andersen's (2018) results support this hypothesis.

CONCLUSIONS

In line with the aim of this systematic, the following conclusions have been drawn. The higher proportion of slow-twitch muscle fibers and the influence of estrogen on metabolism in the female body support the use of high training volumes at low to moderate intensity levels (30–60%). Prolonged muscle tension resulting from high volume at this intensity leads to increased capillary density and mitochondrial volume, thereby improving oxidative metabolism. Metabolic stress rises due to sustained muscle tension, which results in elevated lactate levels and reduced oxygen availability in the active muscle; factors that stimulate mitochondrial protein synthesis. Women tolerate metabolic stress better and have greater blood flow than men, which contributes to greater resistance to muscular fatigue. Additionally, women can perform a higher number of repetitions at an intensity between 40–60% compared to men. At moderate intensities, women also oxidize more fat than men. For these reasons, standardizing training intensity within this range allows for faster recovery in female athletes.

STUDY LIMITATIONS

In this systematic review, the limitations are determined by the inclusion criteria of the studies and their specific characteristics. Variations in measurement instruments, training frequency, statistical techniques, athletic background, or sample size may influence the quality of future reviews.

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EXPLOSIVE POWER OF THE LOWER LIMBS IN FENCING AND TRACK AND FIELD ATHLETES

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ABSTRACT. *Introduction*: Explosive power in the lower limbs is fundamental in fencing, influencing not only the performance, but also the overall dynamics of movements. Similarly, track and field events heavily rely on the strength and explosive capabilities of the lower limbs. *Objective:* The aim of the study was to compare the explosive power of the lower limbs between fencing and track and field athletes. *Material and Methods*: The study was conducted on 70 athletes (35 fencers and 35 track and field athletes) from Iasi, Romania, both males (37.1%) and females (62.9%), aged 13-14 years and 19-20 years. The instruments used to measure the explosive power in athletes were the Standing Long Jump (SLJ) Test and the Vertical Jump Test (Sargent Jump). *Results*: The analysis of the Standing Long Jump (SLJ) Test and the Vertical Jump Test (Sargent Jump) showed no statistically significant differences in the lower limb explosive power between the fencing and the track and field athletes for the first age group, but showed statistically significant differences in the second age group. *Discussion:* The Standing Long Jump (SLJ) Test and the Vertical Jump Test (Sargent Jump) act as benchmarks for younger athletes, allowing coaches to tailor training programs that cater to their specific need, thus enhancing their chances of success in both fencing and track and field. *Conclusions:* The Standing Long Jump Test and the Vertical Jump Test serve as a vital tool in the sports disciplines of athletics and track and field, providing essential metrics regarding explosive lower limb power.

Keywords: fencing; track and field; power; strength; lower limbs.

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INTRODUCTION

Explosive power is the combination of maximum strength and maximum velocity. High value of muscle strength and velocity can lead to good measurement of explosive power (Pandoyo et al., 2020). The evolution of the explosive power is strongly influenced by the transition from preadolescence to adolescence, which represents a critical period of physical and neuromuscular development. During this stage, children undergo significant hormonal, muscular and structural changes that enhance their ability to produce force rapidly. These adaptations include increase in muscle mass, improvements in intermuscular coordination and greater efficiency in motor unit recruitment, all of which contribute to the development of explosive power. During adolescence, individual undergo substantial physiological changes due to hormonal shifts, particularly increases in testosterone and growth hormone levels, which contribute to muscle hypertrophy and enhanced neuromuscular efficiency (Pinto et al., 2017). Research indicates that from approximately ages 13 to 18, adolescents experience peak increases in lower limb muscle strength and explosive power (Ling, 2013). This coincides with critical periods for training interventions that can maximize these physiological developments. Moreover, explosive power in sports involves the ability to generate high force in a short period, which is crucial for actions such as sprinting, jumping, and rapid directional changes.

Explosive power, defined as the ability the explosive power of the lower limbs is fundamental in fencing, influencing not only performance but also the overall dynamics of movements such as lunging and advancing. Explosive power, defined as the ability to exert maximum force in the shortest time, is crucial for athletes who require rapid and forceful movements to execute techniques effectively (Pandoyo et al., 2020). Explosive power is a critical factor in athletic performances of both fencers and track and field athletes.

In fencing, explosive power is essential due to the nature of the sport, which is characterized by quick movements and rapid directional changes. Fencers must generate a substantial force in a brief time, particularly during lunges and rapid retreats. Research indicates that enhanced lower limb strength and explosive power correlate with increased lunge velocity and quicker movements, making this attribute crucial for competitive fencing (Chen et al., 2017; Turner et al., 2014). This power is not merely a byproduct of strength; rather, it is a requisite for executing complex movements required in the sport, where repeated explosive actions are performed in quick succession interspersed with lower-intensity activities (Hagiwara et al., 2023).

Explosive power is a key component for success in track and field disciplines as well (Hermwan et al., 2023; Litao et al., 2023). This power is primarily derived from fast- twitch muscle fibers that are engaged during sprinting, jumping and throwing motions. Athletes in power events, such as sprinters and jumpers, require a unique combination of strength and speed to maximize their performance in high-stake competitions (Loturco et al., 2015). The ability to execute explosive movements is closely related to an athlete's muscle mechanical properties, which can differ significantly depending on the event the athlete is specializing in (Loturco et al., 2015).

Athletic disciplines like sprinting and jumping events rely heavily on the strength and explosive capabilities of the lower limbs. Studies have indicated that greater lower limb strength is positively associated with enhanced sprinting speed and vertical jump height (Exell et al., 2016; O`Driscoll et al., 2024).

Understanding how explosive lower-limb power develops differently between these sports can inform more targeted training programs, adapted to both the athlete's sport demands and biological stage. By comparing fencers and track and field athletes, this research seeks to fill a gap in knowledge about how training specificity and maturation interact to shape explosive performance. Such insights are valuable for coaches and sports scientists aiming to optimize long-term athletic development and prevent training inefficiencies during adolescence.

Our general objective is to compare the explosive power of the lower limbs in fencing and track and field athletes across different ages and stages of pubertal development.

MATERIAL AND METHODS

The present study employed a quantitative, comparative and correlational research design aimed at analyzing the differences in lower-limb explosive power between fencers and track and field athletes across two age groups representing different stages of maturation. The research sought to identify how age and gender influence the development of explosive power, using standardized physical performance tests.

Participants

The approval of the Ethics Committee must be mentioned along with the statement that approved consent was obtained from all subjects.

A total of 70 athletes voluntarily participated in the study. The sample consisted of 40 athletes aged 13-14 years (20 fencers and 20 track and field athletes) and 30 athletes aged 19-20 years (15 fencers and 15 track and field athletes). All participants were male and female competitive athletes from sports clubs in Iasi, Romania.

Anthropometric characteristics such as height (cm) and weight (kg) were recorded prior to the performance tests (Table 1 and Table 2).

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. All participants provided informed consent prior to participation.

Table 1. Anthropometric data of the subjects 13-14 year old

Sport	Number	Gender	Height (cm)	Weight (kg)
Track and field	20	F=14; M=6	160.0±8.9	42.2±4.9
Fencing	20	F=11; M=9	170.2±10.2	56.4±10.9
Total	40	F=25; M=15	165.6±10.6	49.3±11.0

Table 2. Anthropometric data of the subjects 19-20 year old

Sport	Number	Gender	Height (cm)	Weight (kg)
Track and field	15	F=9; M=6	179.9±6.3	64.3±7.9
Fencing	15	F=10; M=5	174.7±9.7	63.9±11.2
Total	30	F=19; M=11	177.3±8.4	64.1±9.5

Procedure

Data collection was conducted in the athletes' regular training environments to ensure ecological validity. Prior to testing, participants performed a 20-minute dynamic warm-up, including light jogging, mobility exercises, running drills and short sprints.

Explosive power was evaluated using two standardized field tests (Mackenzie, 2005):

1. Standing Long Jump (SLJ) Test, which measured horizontal explosive power of the lower limbs. Participants stood behind a marked line with feet shoulder-width apart and jumped forward as far as possible using both legs. The best of two trials was recorded in centimeters (cm).
2. Vertical Jump (VJ) Test, which assessed vertical explosive power. Participants performed a counter movement jump starting from an upright position, using arm swing for maximal effort. The highest jump height, recorded in centimeters (cm), was taken as the final score.

All tests followed the same protocol for both sports and age groups to ensure reliability.

Anthropometric measurements were taken using a stadiometer and a digital scale.

Materials

The materials used in this study included:

- Stadiometer, for measuring height;
- Digital weighting scale (Tanita) for measuring body mass;
- Measure tape and adhesive floor markers for the standing long jump;
- Measure tape and markers;
- Data recording sheets and Jamovi statistical software (version 2.7.6) for data entry and analysis.

All measurements adhered to the International System of Unites (SI) and abbreviations were defined upon first use.

Data analysis

Data was processed and analyzed using the Jamovi statistical software (version 2.7.6). Descriptive statistics (mean ± standard deviation) were calculated for all variables. The Shapiro–Wilk test was applied to assess data normality. Depending on data distribution, Independent Samples T-Tests or Mann–Whitney U tests were used to compare explosive power between groups.

To evaluate the relationship between gender and performance indicators (SLJ, VJ), Pearson's or Spearman's correlation coefficients were computed. Statistical significance was set at $p < 0.05$.

RESULTS

Track and field athletes achieved a mean Standing Long Jump (SLJ) distance of 196.4 ± 13.3 cm, while fencers jumped slightly shorter distances, with a mean SLJ of 194.5 ± 21.3 cm. Vertical jump (VJ) performance was similar between groups, with track and field athletes averaging 35.9 ± 5.0 cm and fencers 35.8 ± 5.9 cm. Only the best performance jump for each individual was recorded and reported (Table 3).

Table 3. Explosive power performance in the 13-14 years old athletes

Variables	Track and field	Fencing
SLJ (cm)	196.4±13.3	194.5±21.3
VJ (cm)	35.9±5.0	35.8±5.9

Track and field athletes achieved a mean SLJ distance of 240.4 ± 15.5 cm, whereas fencers recorded a mean SLJ distance of 221.5 ± 13.8 cm. VJ performance was 52.1 ± 10.1 cm for track and field athletes and 39.4 ± 5.6 cm for fencers. Only the best performance jump for each individual was recorded and reported (Table 4).

Table 4. Explosive power performance in the 19-20 year old athletes

Variables	Track and field	Fencing
SLJ (cm)	240.4±15.5	221.5±13.8
VJ (cm)	52.1±10.1	39.4±5.6

Prior to conducting the comparative analysis, the normality of data distribution was verified using Shapiro-Wilk test for each variable and sport group.

For the 13-14 year old athletes, the SLJ data were normally distributed ($p > 0.05$), while the VJ data showed a non-normal distribution in the track and field group ($p = 0.032$). Therefore, an independent samples t-test was applied for the SLJ, and a non-parametric Mann-Whitney U test was used for VJ. Homogeneity of variances was verified with Lavene's test ($p = 0.051$), indicating equal variances between sports and supporting the use of the standard t-test. The results of the 13-14 years group indicated no statistically significant differences between fencing and track and field athletes in either SLJ ($t(38) = 0.338$, $p = 0.737$, $d = 0.107$) or VJ ($U = 192$, $p = 0.839$) (Table 5).

Table 5. Statistical analysis for the 13–14-year-old athletes

		Shapiro-Wilk	Levene's	Test statistic	Df	p-value	Effect size Cohen's d
SLJ (cm)	T&F	0.138	0.051	t=0.338	38	0.737	0.107
	Fencing	0.203					
VJ (cm)	T&F	0.032	-	U=192	-	0.839	-
	Fencing	0.139					

For the 19-20 years group, all variables met the normality assumption ($p>0.05$), allowing the use of independent samples t-tests for both SLJ and VJ. Homogeneity of variances was verified using Levene's test. The results indicated equal variances for SLJ ($F(1,28) = 0.292$, $p = 0.593$) and unequal variances for VJ ($F(1,28) = 7.663$, $p = 0.010$). Consequently, the Student's t-test was used for SLJ and the Welch's t-test for VJ. Significant differences were observed in both tests, with track and field athletes achieving higher values compared to fencers. The SLJ showed a significant difference ($t = 3.54$, $p = 0.001$, $d = 1.29$), while the VJ, analyzed with Welch's correction due to unequal variances, also revealed a highly significant difference ($t = 4.26$, $p < 0.001$, $d = 1.55$) (Table 6).

Table 6. Statistical analysis for the 19–20-year-old athletes

Variables	Test statistic	Df	p-value	Effect size Cohen's d
SLJ (cm)	t=3.54	28	0.001	1.29
VJ (cm)	t=4.26	28	0.001	1.55

To further explore potential factors influencing explosive power, the relationship between gender (female = 1, male = 0) and performance in the SLJ and VJ was analyzed withing each sport and age group. Pearson correlations were used when the performance variables were normally distributed and Spearman correlations were applied when normality assumptions were not met.

In the 13-14-years- old track and field group, Pearson correlation indicated no significant relationship between gender and SLJ performance ($r = –0.047$, $p = 0.844$), while Spearman correlation showed no significant association between gender and VJ performance ($\rho = –0.076$, $p = 0.749$), suggesting that male and female athletes in this group performed similarly in both tests. In the 13–14-year-old fencing group, strong negative correlations were observed for both SLJ ($r = –0.777$, $p < 0.001$) and VJ ($r = –0.799$, $p < 0.001$), indicating that male fencers exhibited substantially higher explosive strength than female fencers (Table 7).

Table 7. Correlations between gender and SLJ and VJ in the 13-14 year old athletes

		r/p	***p***
Track and field	SLJ	-0.047	0.844
	VJ	-0.076	0.749
Fencing	SLJ	-0.777	<0.001
	VJ	-0.799	<0.001

For the 19–20-year-old track and field group, very strong negative correlations were found for SLJ ($r = –0.771$, $p < 0.001$) and VJ ($r = –0.903$, $p < 0.001$), reflecting the greater performance of male athletes in this older age group. Similarly, in the 19–20-year-old fencing group, the correlation between gender and VJ remained very strong and negative ($r = –0.890$, $p < 0.001$), while SLJ also showed a strong negative correlation ($r = –0.909$, $p < 0.001$) (Table 8).

Table 8. Correlations between gender and SLJ and VJ in the 19-20 year old athletes

		r	***p***
Track and field	SLJ	-0.771	<0.001
	VJ	-0.903	<0.001
Fencing	SLJ	-0.909	<0.001
	VJ	-0.890	<0.001

DISCUSSION

For the 13–14 year old group, no statistically significant differences were found in either the SLJ (t = 0.338, p = 0.737, d = 0.107) or the VJ (u = 192, p = 0.839) between fencing and athletics athletes. Both groups demonstrated comparable levels of explosive strength, suggesting that at this developmental stage, sport-specific training has not yet produced differentiated effects on lower-limb power. This finding is consistent with research showing that between ages 13 and 18, adolescents undergo substantial physiological transformations — including increases in testosterone and growth hormone — that lead to muscle hypertrophy, improved neuromuscular efficiency, and enhanced motor control (Pinto et al., 2017; Ling, 2013; Hermawan et al., 2023). These changes mark the onset of the critical growth window for strength and power development, during which biological maturation exerts a stronger influence on performance than training specificity. As Ravi (2024) and Ling (2013) suggest, the explosive capabilities of adolescents begin to accelerate around age 13 but reach their peak only in late adolescence. Therefore, the absence of significant differences between fencing and athletics athletes at 13–14 years likely reflects a stage where maturation and general training dominate performance, while sport-specific adaptations are still emerging.

In contrast, the results from the 19–20 years group revealed highly significant differences between the two sports. Athletics athletes achieved greater performance in both the SLJ (t = 3.54, p = 0.001, d = 1.29) and VJ (t = 4.26, p < 0.001, d = 1.55), with large to very large effect sizes. These outcomes clearly indicate a superior level of explosive strength in track and field athletes compared to fencers. Such differences can be attributed to long-term, sport-specific training adaptations that accumulate during late adolescence and early adulthood (Litao et al., 2023). Track and field athletes typically engage in more frequent and specialized plyometric and power-based training, which enhances the stretch-shortening cycle and neuromuscular coordination required for explosive performance (Jastrzębski et al., 2014; Shuai et al., 2025). These exercises directly improve maximal force production and jump performance, explaining the higher results in athletics athletes. Conversely, fencing prioritizes agility, reaction time, and unilateral explosive actions rather than maximal jump power (Turner et al., 2014), with only one general physical training session per week—limiting the development of maximal lower-limb power.

The comparison across age groups also illustrates a developmental trajectory: while early adolescents display little variation between sports, differences become more pronounced after 18 years of age. This supports the idea that sport-specific differentiation in explosive strength emerges only after the major phase of physical maturation, when neuromuscular and hormonal systems stabilize and the effects of long-term training accumulate (Ling, 2013; Litao et al., 2023; Pinto et al., 2017). Studies have shown that lower-limb power output continues to increase significantly through late adolescence, particularly in athletes exposed to structured plyometric and resistance training (Shuai et al., 2025; LI et al., 2025; Chen, 2023). The superior performances observed among 19–20-year-old athletics athletes thus reflect both physiological maturity and the cumulative benefit of years of targeted training for explosive strength.

From a practical perspective, these findings suggest that multilateral physical development should be emphasized during early adolescence, as athletes in this age group are still undergoing foundational neuromuscular and hormonal changes. Coaches of younger athletes should prioritize general strength and coordination work, postponing narrow specialization until after peak height velocity and the onset of stable power development. For fencing coaches, progressively integrating bilateral and plyometric exercises could enhance leg power and complement the sport's agility-oriented demands. Meanwhile, athletics coaches can interpret these results as evidence of the effectiveness of plyometric and power-oriented programs, particularly during late adolescence, when such training aligns with peak physiological readiness for strength development (Jastrzębski et al., 2014; Shuai et al., 2025).

The correlations between gender and explosive performance further reinforce these patterns. In the younger athletics group (13–14 years), both standing long jump and vertical jump showed very weak, non-significant correlations with gender (r = –0.047 to -0.076, p > 0.05), indicating that males and females perform similarly before major hormonal divergence. This aligns with previous findings showing minimal gender-based performance differences in prepubescent and early pubescent athletes (Thomas et al., 2020). However, in fencing, where maturation may occur earlier, strong negative correlations were observed even in this younger group (r = –0.777 to –0.799, p < 0.001), possibly reflecting earlier pubertal onset among female fencers.

By late adolescence (19–20 years), strong and significant gender correlations emerged in both sports (r = –0.890 to –0.909, $p < 0.001$), indicating that male athletes exhibited superior explosive strength. This is consistent with established evidence that testosterone levels in males drive greater muscle hypertrophy and strength gains, particularly in power-oriented activities (Handelsman et al., 2018; Mateo-Orcajada et al., 2022). Thomas et al. (2020) further showed that while males continue improving in jumping performance up to ages 16–17, females tend to plateau earlier, around 12–13 years old. These physiological and hormonal differences become decisive in late adolescence, explaining the stronger gender-performance associations observed in the older groups.

Overall, the present findings align closely with existing literature, supporting the conclusion that explosive strength development during adolescence is governed first by biological maturation and later by sport-specific training. Between 13–14 years, general growth processes overshadow training effects, whereas after 18, differentiated training loads and physiological specialization yield marked inter-sport and inter-gender differences. These insights emphasize the need for age-appropriate and gender-sensitive training approaches in both fencing and track and field, ensuring optimal development of explosive power across the athlete's growth trajectory.

CONCLUSIONS

This study compared the explosive power of the lower limbs in fencing and track and field athletes across different ages and stages of pubertal development. The results showed that at 13–14 years, there were no significant inter-sport differences in jumping performance, suggesting that explosive strength was primarily influenced by biological maturation rather than sport-specific training. However, at 19–20 years, track and field athletes displayed significantly greater performance, reflecting the effects of long-term, power-oriented training adaptations.

Gender differences were minimal in early adolescence but became pronounced in late adolescence, with male athletes outperforming females in both jump tests. These findings confirm that both maturation and training specialization play key roles in developing explosive power.

Overall, the study highlights that sport-specific differentiation in lower-limb power emerges after pubertal development and that early training should emphasize general physical preparation. Future research should explore longitudinal changes and include broader samples to further understand the interaction between growth, gender, and training specialization.

AUTHOR CONTRIBUTIONS

Ioana-Alexandra Radu and Luisa Cristiana Gamen contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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THE IMPACT OF EXTRACURRICULAR ACTIVITIES AT THE UNIVERSITY LEVEL. A SYSTEMATIC REVIEW

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ABSTRACT. *Introduction*: The holistic approach to the educational process involves, in addition to the transmission of theoretical notions, the development of students' social, emotional and physical skills. These dimensions are fundamental for a healthy and balanced development. In this context, extracurricular activities (EA) at the university level create the premises of an extended framework, in which students explore, cooperate, improve their self-image and achieve better results in exams. In a competence-oriented educational system, EA provide relevant contexts for experiential learning, for character formation and for the development of transversal skills: teamwork, responsibility, communication skills. Unlike curricular activities, which have clearly defined objectives, EA offer students a greater degree of freedom, choice and voluntary involvement, which favors intrinsic motivation and the assumption of an active role in the learning process. *Objective*: to present the relationship between students' involvement in EA and different aspects of their lives. *Materials and methods*: A systematic review of the scientific literature was conducted for 21 articles, selected from the Google Scholar platform, in which the impact/effect of EA on students was presented. *Results*: Following the analysis, positive correlations were found between the participation of students from different fields in EA and the improvement of indicators such as self-confidence, collaboration, academic performance, etc. *Conclusions*: The involvement of students in EA is not only a goal of international forums in terms of education, but also represents a way to improve the academic, physical and emotional situation of students.

Keywords: extracurricular activities; academic success; personality development; collaboration; sport.

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INTRODUCTION

The factors that contribute to students' academic performance are numerous (Lumely et al., 2015): previous academic performance, study skills, attitude, behavior and motivation, time management, physical activity and coping strategies. Therefore, it is necessary for students to establish a balance between study, relaxation and other commitments, because this has an impact on the quality of life (Zhang et al., 2012). Balance can also be achieved through EA which, unlike the mandatory activities included in the curriculum of higher education degree programs, are voluntary, non-academic activities, in which students make new friends, have fun, have new experiences and challenges, participate in different cultural, social and sports activities. Each club or sport is different, so students meet different people in all the different groups. But they also meet people with the same experiences, with whom they share common interests and passions. EA take place outside the classroom, either within the educational institution or in clubs, workshops, gyms, religious structures, etc. (Stuart et al., 2011).

EA emerged in the United States in the 19th century, as an additional part of the normal academic program, having some practical or vocational interest. The first EA began at Harvard and Yale Universities. They were literacy clubs, which consisted of various debates. American students were the first to initiate sports clubs (Casing, 2024).

Lunnenburg (2010) believes that EA serve the same objectives and functions as compulsory and optional courses in the school curriculum, allowing students to apply the knowledge learned in other courses. Among the benefits of EA, we mention: improving academic performance (Freeman, 2017), developing social skills (Jahan, 2024), leadership qualities, reducing stress (Zeidan et al., 2025) and building a healthy and balanced life in general. There are many forms of EA, such as sports, clubs, student newspapers, music, art and theater (Massoni, 2011). Participation in EA contributes to professional development, to the comprehensive and harmonious fulfillment of the human being (Darling et al., 2017). By engaging in such activities, students make stronger connections with their colleagues, administrators and communities to which they belong (Feraco et al., 2023), which have numerous positive consequences on their learning and behavior (Juma, 2015). Involvement in EA is considered part of the total social experience in students' lives (Behtoui, 2019), reduces stress, improves the interpersonal skills of young people and has a positive academic impact. Wilson (2009) believes that participants in EA are less likely to engage in problematic behaviors. Olson (2008), in his study, shows that students who enrolled in fine arts activities had significantly lower absenteeism rates than those who did not participate in such activities, and Behtoui (2019) concludes that participation in EA reduces school dropout in higher education institutions and increases student self-esteem. It is also worth mentioning the importance of these activities for good health and for the development of the body, mind and soul of young people. Thus, sports games, such as badminton, provide them with good health, develop team spirit and competition, strong characters and a sense of belonging to a community or idea, build healthy moral values and create elites (Prodea et al., 2018). Participation in athletics, for example, leads to higher self-esteem and improved status among peers, which some argue is a deterrent to antisocial behavior (Brown, 2000). Gynosian et al. (2020) believes that the purpose of EA is to capitalize on the individual talents, skills, and abilities of participants to provide them with a unique and multifaceted identity. Language and cultural exchanges open doors to learning new languages, experiencing different cultures, and building international friendships (Sandal et al., 2020). Students involved in EA meet new people, learn about teamwork, and sometimes end up conforming less to gender stereotypes.

The purpose of this systematic review of the scientific literature is to determine the relationship between students' involvement in EA and various aspects of their lives by formulating an answer to the question: "What is the impact of EA on students?" The objective of this study is to present the relationship between students' involvement in EA and different aspects of their lives.

MATERIAL AND METHODS

This systematic review was conducted according to the Prisma Statement (Page et al., 2020).

Search strategy

We performed a detailed search on the Google Scholar platform to identify original studies that present the impact/effect of EA on students. Search criteria included terms such as "impact", "effect", "extracurricular activities", "students", "university", "higher education", but a combined search of these keywords was also performed, along with the option to identify them in the abstract.

Study selection and eligibility criteria

Studies were considered eligible for inclusion if they met the following criteria: (a) published in English; (b) available in full version; (c) articles/theses that respect the research topic.

The exclusion criteria were as follows: (a) the word “student” is used, but the meaning is “pupil”; (b) they are reviews, editorials, cross-sectional studies or conference abstracts; (c) articles that do not refer to higher education.

21 articles published between 2006-2025 were retained.

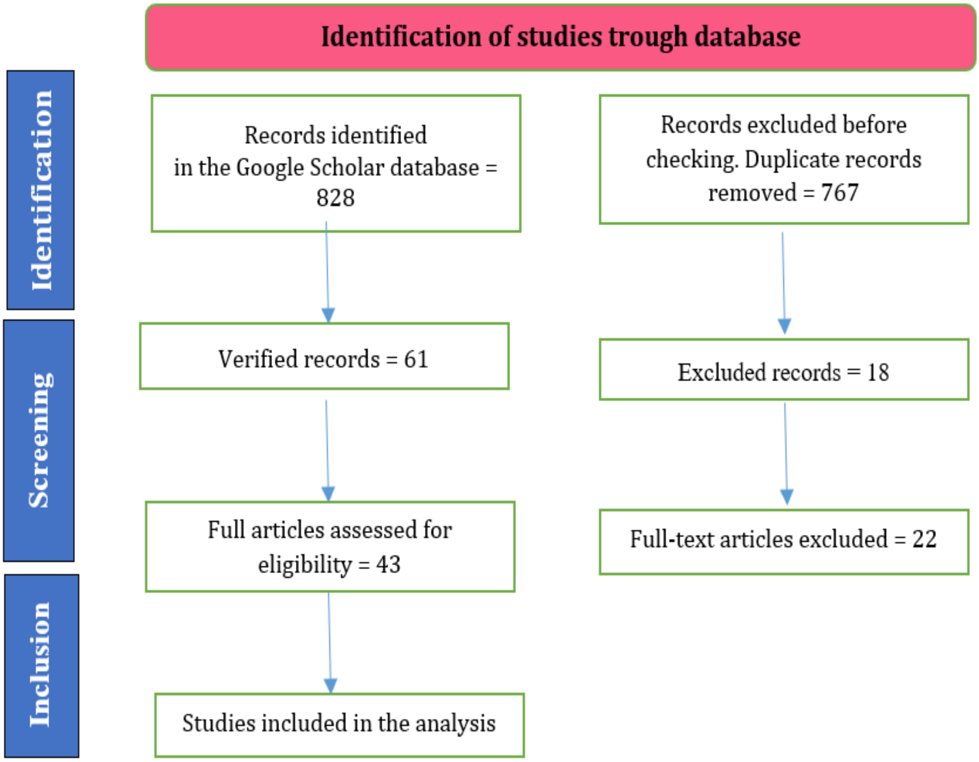

Figure 1. PRISMA diagram

RESULTS

The PRISMA flow chart (Fig. 1) shows the literature search process. 828 potentially suitable studies were identified to analyze the impact of extracurricular activities on students. After performing title screening and full eligibility analysis, 21 articles were retained. These articles were published between 2006 and 2024, as shown in Figure 2.

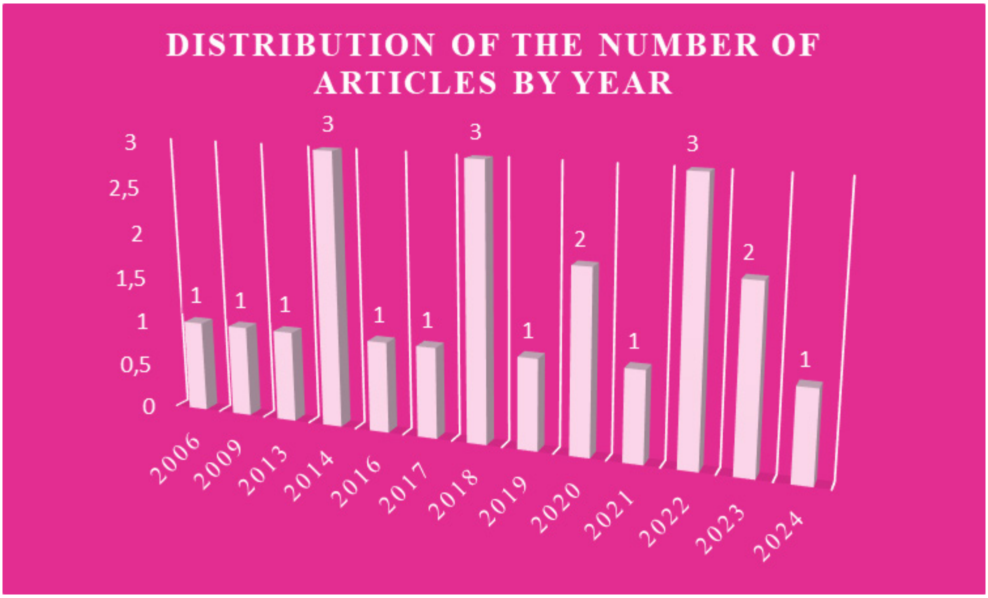

Figure 2. Distribution of the number of articles by year

The 21 articles analyzed target students from various universities around the world, with the research method used predominantly for data collection being the questionnaire (16). Interviews, cross-sectional surveys and case studies were also used. One of the studies systematically analyzed 39 articles published between 2010 and 2021, which address the impact of EA on students' academic success and employability.

DISCUSSIONS

The impact of EA is evident in several aspects of students' lives, with the selected articles testifying to this. We have structured these aspects into several categories, which we present below.

Academic performance

Eight of the selected articles highlight the impact of EA on students' academic performance. Rafiullah & Khan (2017), Zaki (2022), Nguyen (2022), Guilmette & al. (2019), Wang & Shiveley (2009) and Sathiyasenan et al. (2020) present the positive impact of EA on improving students' academic performance. On the contrary, the results of Sabuj's et al. (2018) study indicate the existence of a negative, but insignificant, association between students' involvement in general EA and academic performance. Specifically, involvement in social activities has a significant negative impact on academic performance. Syafiq et al. (2014) concludes that there is no significant positive association between participation in EA and students' academic achievements. Following the synthesis carried out, Ribeiro et al. (2023) finds that the vast majority of EA have a positive impact on students' academic success. Those that show a negative impact are residual.

Employability and business creation/entrepreneurship

Regarding the impact of EA on students' success in getting a job, creating a business, seven studies refer to this aspect. Ribeiro et al. (2023) indicates the positive impact that EA represent on the employability of university students, and the results of Kanar's & Bouckenooghe (2021) study suggest that EA play an important role in shaping the job search process of university students, influencing their confidence in finding a job. Arranz et al.'s (2016) analysis demonstrates that extracurricular activities generate positive attitudes towards entrepreneurship, but reduce the intention and ability to start a business. The study presents the effects of EA on entrepreneurial skills and their strategic and methodological implications. Mishra's & Aithal (2023) study findings reveal that engaging, well-structured EA are effective in developing holistic, industry-ready individuals, while Cordea's (2024) study findings suggest that EA equip students with the skills needed to engage in new business creation. Buckley & Lee (2018) finds that respondents attributed participation in EA to the positive development of a range of skills and abilities associated with employability, and Ward & Yates (2013) argues for a cocurricular transcript that could track, document, and communicate the types of activities that employers value.

Collaboration, cohesion, team spirit and communication

Mishra & Aithal (2023) recalls, among the results of the study, that in addition to developing communication skills and team spirit, students who participate in EA learn task-oriented roles and relationship-oriented roles, which promote cohesion and collaboration in the team and make students independent and confident. The same results are also indicated by Buckley & Lee (2018): involvement in EA contributes to the development of a range of skills and abilities associated with teamwork, problem solving and communication. Sathiyasenan et al. (2020) mentions that EA contributed to the enhancement of interpersonal skills. In the same vein, Bahdi (2014) believes that there is a positive relationship between extracurricular involvement and oral competence. The findings also show that a well-planned and organized EA is an effective way to improve the oral production of foreign language learners.

Self-confidence and improved health

Buckley and Lee (2018) list several benefits of extracurricular activities: reducing stress, improving physical health, developing attachment to the institution, involvement in the campus and in the community, offering new opportunities and challenges to explore. All of these are considered to contribute positively to the overall student experience in higher education (Gherman et al., 2021). For Cordea (2014), EA have real learning benefits for students and there is certainly evidence that they increase self-confidence, Higgins (2006) demonstrates that participation in EA has significant effects on students' psychological development, and Guilmette et al. (2019) positively associated EA with self-goal-setting strategies, which in turn were linked to higher levels of emotional well-being.

Creativity, originality, behavior

The results of Sabuj's et al. (2018) study show that while involvement in social activities has a significant negative impact on academic performance, other EA, such as sports, cultural activities, and political activities, do not have a significant impact on student performance, and Higgins' (2006) study demonstrates that participation in EA has significant effects on students' psychological development. Sports, clubs, and volunteering affected students in different ways. In fact, Saqib et al. (2018) highlights that for Indian and Pakistani students, sports are the most frequently adopted type of EA, being less inclined towards activities related to fine arts and literature. Participation in activities predicted changes in identity status scores over time. Yongshuma's & Fernandob (2024) study adds new information to the existing body of knowledge on how students' EA influence their levels of innovation, creativity and originality, Mishra's & Aithal (2023) study confirms that participation in EA helps in character development and social skills development, and Khanna et al. (2020) highlights that most students agree that there is a positive impact of EA on their individual skills and that steps should be taken to implement them in more colleges and universities. Rafiullah et al. (2017) however finds that there is a minor change in the behavior of students who participated in EA. Unfortunately, not all students benefit equally from involvement in EA. Providing a wide range of accessible opportunities for students can promote equity in participation in this type of activities (Winstone et al., 2022).

Table 1. Results of selected studies

Study no	Target group	Methods	Rezults
[1]	150 students	Questionnaire	The results show that there is no significant positive association between students' academic performance and participation in EA.
[2]	39 articles published between 2010–2021 in the Scopus and WoS databases	Narrative synthesis	The results indicate a positive impact of most EA on students' academic success. EA with negative impact are residual.
[3]	1475 students	Questionnaire	EA generate positive attitudes towards entrepreneurship, but reduce the intention and ability to start a business. The study presents the effects of EA on entrepreneurial skills and their strategic and methodological implications.
[4]	200 students	Cross-sectional survey	The results of the current study showed that university students in Lahore who participated in EA improved their academic performance and self-concept. The study indicated changes in the behavior of students participating in EA.
[5]	306 students	Questionnaire	The results emphasize the importance of EA in students' job search and their confidence in finding one.
[6]	507 students	Questionnaire	The results of the study increase the information regarding the influence of EA on student performance in terms of innovation, creativity and originality.
[7]	24 students	Case study	The results indicate positive influences on the academic and social skills of students who participate in EA, motivating them to participate in such activities in the future.
[8]	100 students	Questionnaire	The analysis shows that extracurricular and co-curricular activities improve academic and social performance, help in character development and social skills development, students have better experiential learning, develop their communication skills and team spirit, learn task-oriented roles and relationship-oriented roles. Such activities promote team cohesion and collaboration, develop independence and confidence. EA proves their effectiveness in the holistic training of students preparing for the industry.
[9]	285 students	Questionnaire	Participating in EA gives students the opportunity to "learn by doing," through action and experience (68% of respondents). EA have benefits in terms of learning, increasing self-confidence and providing skills for creating businesses.

Study no	Target group	Methods	Rezults
[10]	270 students	Interview/ Questionnaire	The results indicate a negative but non-significant association between involvement in general EA and academic performance. A significant negative impact on academic performance, as measured by cumulative grade point average (GPA), is found only following involvement in social activities, while EA such as sports, cultural activities, and political activities do not have a significant impact on a student's GPA.
[11]	300 students	Questionnaire	The positive effects that these activities have on students' academic performance are undeniable.
[12]	655 students	Questionnaire	This study demonstrated that participation in EA has significant effects on students' psychological development. Sports, clubs, and volunteering affected students in different ways. Participation in activities predicted changes in identity status scores over time.
[13]	72 students	Questionnaire	Most students agree about the positive impact of EA on their individual skills and their implementation in colleges and universities.
[14]	401 students	Questionnaire	The results showed that there is a positive association between past and present EA of university students and self-goal-setting strategies. The latter influenced academic success and emotional well-being. Universities and colleges can encourage students to participate in EA for a positive adaptation.
[15]	227 students	Questionnaire	Students are not equally involved in EA. Providing multiple accessible opportunities for students can promote equity in participation in EA.
[16]	42 students	Questionnaire	The study highlights the positive association between EA and oral proficiency. The findings also show that a well-planned and organized EA is an effective way to improve the oral production of foreign language learners.
[17]	28 workforce recruiters	Questionnaire	The authors emphasize the importance of having a varied offering of EA to enhance the curriculum, as well as a framework for the potential development of a cocurricular transcript that tracks, documents, and communicates the types of activities valued by employers.
[18]	5078 students	Questionnaire	Respondents believed that participation in EA contributed to the positive development of skills and competencies associated with employability, such as communication, teamwork, and problem-

Study no	Target group	Methods	Rezults
			solving. Participants indicated that by managing their time effectively and improving their prioritization skills, they improved their self-management. Benefits to the student experience: EA reducing stress, improving physical health, developing attachment to the institution, involvement in the campus and in the community, offering new opportunities and challenges to explore.
[19]	922 students	Comparative analysis	Students achieved much higher retention and graduation rates, maintained better overall averages, and had higher achievement rates when engaging in any of the proposed EA.
[20]	250 students	Questionnaire	The analysis showed that most students do not engage in EA. Some relax in their free time, motivating the traditional perception that involvement in such activities will distract them from their studies, others do not participate in AE due to the responsibilities they have towards their families. The most common types of EA adopted by students are sports activities, they are less inclined towards activities related to literature and fine arts.
[21]	200 students	Structured interviews	The results and responses to the structured interviews showed that EA contributed to improving students' grades and enhanced their interpersonal skills.

CONCLUSIONS

The findings of this systematic review, based on 21 studies published between 2006 and 2024, confirm that university students' participation in EA has a significant impact on their academic, professional, and personal development. Engagement in sports, cultural, artistic, or volunteer activities enhances academic performance, fosters the development of transversal competences-such as communication, teamwork, leadership, and critical thinking-and contributes to the formation of a balanced personal and professional identity. Moreover, extracurricular involvement supports self-regulated learning, intrinsic motivation, and adaptability to professional environments.

From a psychological perspective, EA reduce stress, strengthen self-confidence, and promote well-being and social inclusion. To maximize these benefits, universities should integrate diverse and accessible extracurricular programs that complement formal education. Overall, EA represent a strategic instrument for holistic student development and for strengthening a competence-oriented, balanced, and human-centered model of higher education.

AUTHOR CONTRIBUTIONS

All authors contributed equally. All authors have read and agree to the publication version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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ASSESSMENT OF SELF-PERCEPTION AND SELF-ATTITUDES IN WOMEN'S RUGBY SEVENS ATHLETES

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ABSTRACT. The purpose of the present study is to analyze the levels of self-perception among Romanian female Rugby Sevens players, both juniors and seniors, by identifying potential differences according to their performance level. We hypothesize that female Rugby Sevens players generally exhibit high levels of self-perception. Furthermore, we assume that differences in self-perception exist between club players and those competing for the national team. The study included 97 female Rugby Sevens players participating in the 2024 edition of the Romanian National Championship: 29 senior players with a mean age of 21.1 ± 4.8 years and 68 junior players with a mean age of 15.2 ± 1.5 years. Self-perception was assessed using the PAS Questionnaire: Perceptions and Self-Attitudes. Statistical analyses were performed with IBM SPSS Statistics 20, applying the Shapiro–Wilk test, Kolmogorov–Smirnov test, Frequencies, Independent-Samples T Test, and the nonparametric Mann–Whitney U test. The results indicate generally high levels of self-perception among female Rugby Sevens players, although medium and low values were observed on certain scales. Additionally, statistically significant differences were found between club players and national team players, both at junior and senior levels.

Keywords: Rugby sevens; female athletes; self-perception; self-attitudes; performance

INTRODUCTION

Sevens rugby is a dynamic and demanding sport that requires not only exceptional physical abilities but also specific psychological traits (McAuliffe, 2021; Kerr, 2019; Dohme et al., 2017). Confidence represents a fundamental factor in

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sports performance, strongly influencing athletes' commitment and ability to cope with competitive challenges. At both junior and senior levels, this psychological dimension contributes to individual progress, team cohesion, and competitive outcomes (Castro-Sánchez et al., 2019; King et al., 2019; Fernández-García et al., 2015).

Several authors argue that success in elite sport is closely linked to psychological preparation, with mental skills playing a crucial role in achieving and sustaining peak performance (Van Rooyen, 2015; MacNamara et al., 2010). Career development is strongly influenced by attributes such as commitment, perseverance, determination, competitiveness, and self-confidence (Hendricks, 2012; MacNamara et al., 2010; Kruyt & Grobbelaar, 2019; Sanader et al., 2019; Sanader et al, 2021). Confidence in particular underpins motivation and the ability to face competitive demands (Mellalieu, 2017; Collins et al., 2019; Piepiora et al., 2020; Alexe & Sandovici, 2018).

In team sports, athletes must balance individual and collective goals, navigating the complexity between personal and social identities (Campo, 2019). Optimism and positive thinking are essential for overcoming setbacks and maintaining the motivation and energy required for performance. Belief in one's abilities further enables athletes to meet challenges, exceed limits, and sustain the conviction of achieving excellence (Nicolescu, 2021; Nicolescu & Glavan, 2022; Gledhill & Harwood, 2015; Mellalieu, 2017; Collins et al., 2019).

Personality traits and psychological factors significantly influence elite players' performance, with outcomes shaped by both environmental interactions and genetic predispositions (O'Neill et al., 2022). Cognitive control helps athletes prevent negative thoughts that undermine self-confidence and concentration, while maintaining focus under pressure is vital for task execution (Kruyt & Grobbelaar, 2019; Piepiora et al., 2020; Nicolescu, 2021).

Self-esteem has also been associated with psychological well-being. However, no significant differences have been observed between athletes in individual versus team sports. In professional hockey players, studies highlight positive correlations between emotional regulation, emotional intelligence, and self-confidence, and negative associations with cognitive anxiety, underlining the role of emotional intelligence in competitive states (Tinckler et al., 2021).

Decision-making under time pressure requires motor intelligence and technical ability, but repeated high-stress situations may lead to impulsive and risky actions. Psychological skills such as motivation, confidence, commitment, focus, adaptability, and self-regulation are therefore crucial in rugby talent identification and transition to elite levels (McAuliffe, 2021; Kerr, 2019; Dohme et al., 2017). These attributes allow players to respond effectively to competitive demands (Bitchell et al., 2020).

Lack of psychological resources, such as motivation, commitment, confidence, focus, and self-regulation, may hinder talent development in rugby, as consistently reported in previous studies (Dohme et al., 2019; Drew et al., 2019; Cowden et al., 2016). A study of 24 female rugby sevens players from Canada and Wales emphasized that rugby fosters a sense of empowerment, offering confidence, challenge, self-control, and opportunities to demonstrate gender equality (Kim et al., 2023).

MATERIAL AND METHODS

The purpose of the present study is to analyze the levels of self-perception among Romanian female Rugby Sevens players, both juniors and seniors, by identifying potential differences according to their performance level. We hypothesize that female Rugby Sevens players generally exhibit high levels of self-perception. Furthermore, we assume that differences in self-perception exist between club players and those competing for the national team.

Participants

The study included 97 female Rugby Sevens players participating in the 2024 edition of the Romanian National Championship: 29 senior players with a mean age of 21.1 ± 4.8 years and 68 junior players with a mean age of 15.2 ± 1.5 years. The study was approved by the Ethics Committee, and informed consent was obtained from all participants prior to their inclusion in the research.

Procedure and materials

Self-perception was assessed using the PAS Questionnaire: Perceptions and Self-Attitudes. The PAS questionnaire assesses four key aspects of an individual's psychological profile and their tendency to respond honestly or distort answers: self-image, self-esteem, self-efficacy, achievement, facade tendency, self-deception, self-presentation, exaggeration, self-depreciation, gratitude, regrets, and moral integrity (honesty, sincerity, morality). Each of the four dimensions is measured using 21 items grouped into three factors. Extreme scores on the first three scales may indicate potential positive or negative response distortions, while high scores on the Moral Integrity scale can alert to issues with honesty and moral flexibility (Constantin et al., 2022).

Data analysis

Statistical analyses were performed with IBM SPSS Statistics 20, applying the Shapiro–Wilk test, Kolmogorov–Smirnov test, Frequencies, Independent-Samples T Test, and the nonparametric Mann–Whitney U test.

RESULTS

Hypothesis testing 1

Junior rugby player

To determine the absolute and relative frequencies of the variables, the Frequencies test was applied, enabling the identification of trends in the psychological characteristics of junior rugby players.

The analysis of self-image, including self-esteem, self-efficacy, and achievement, indicates that players generally hold a positive perception of themselves. High frequencies of positive responses in the self-esteem dimension suggest that athletes evaluate their value and competencies optimistically. Regarding self-efficacy, most players (35%) consider themselves capable of achieving their goals, supporting the enhancement of sport performance. However, 25% reported lower scores, which may indicate reduced confidence and difficulties in maintaining focus during competition. Additionally, athletes tend to value and frequently recognize personal achievements, reflecting a strong motivation essential for performance development (Fig. 1.a).

The distribution of responses regarding the facade tendency shows that most junior players (80%) scored between 5 and 10, suggesting an overly positive self-image. High self-deception scores further indicate an idealized self-assessment, while lower concern for self-presentation reflects greater authenticity but also potential disinterest in team image. Conversely, 37% reported higher concern, pointing to reliance on external validation. Regarding exaggeration, 58% displayed a realistic self-perception, whereas 31% tended to overstate achievements and abilities (Fig. 1.b).

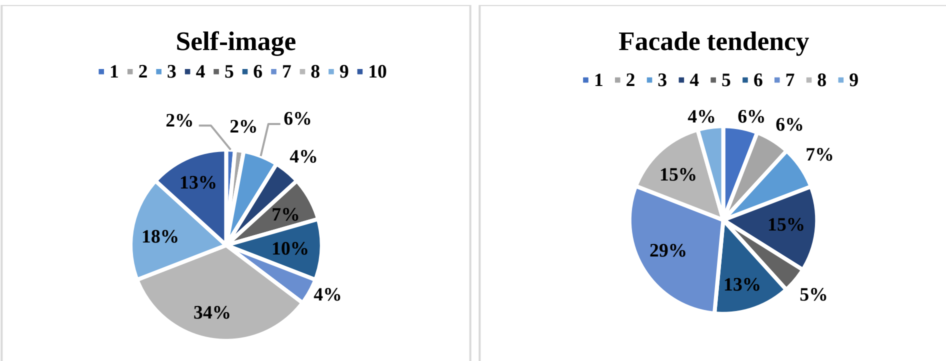
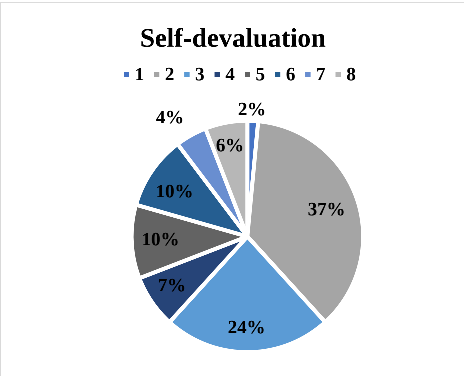


Fig. 1. Frequency of responses for size (a) self-image; (b) facade tendency

In the self-devaluation facet, 62% of players scored low (1–3), suggesting optimism and a lack of major regrets. Gratitude showed predominantly low scores (63%), indicating a more individualistic perspective and limited appreciation for external support, while 37% reported higher values, reflecting reduced awareness of contributions from coaches, teammates, and family. High regret scores (57%) suggest frequent reflection on mistakes or missed opportunities, potentially undermining confidence, whereas 43% may display stronger emotional regulation or avoidance of responsibility. Regarding self-depreciation, 59% reported positive self-perceptions and a sense of accomplishment, while 24% showed discouragement and pessimism (Fig. 2.a).

High moral integrity among junior rugby players is evident, with 77% demonstrating well-defined values that likely enhance team cohesion and a healthy competitive climate. Honesty scores were also high (70%), indicating that athletes value sincerity in sport and daily life. Elevated scores in honesty and morality facets (79%) suggest that players take responsibility for their actions and adhere to clear ethical principles both on and off the field (Fig. 2.b).



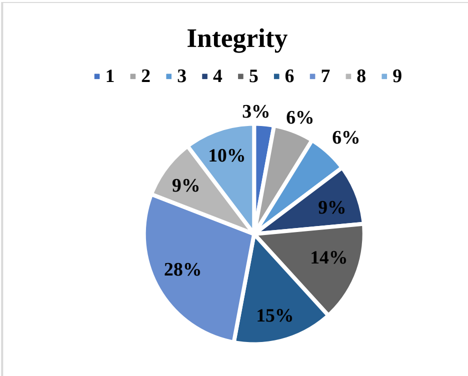


Fig. 2. Frequency of responses for size (a) self-devaluation; (b) integrity

Senior rugby player

The frequency analysis of psychological characteristics among senior rugby players highlights generally positive self-perceptions, though with notable variability. Regarding self-image, 21% of players reported high scores (8–9), 17% reached the maximum (10), while 14% scored lower, suggesting fluctuations influenced by past experiences, results, or team context.

Self-esteem was also high, with 38% of athletes reporting very strong self-worth, although 14% indicated moderate or lower confidence. Similarly, self-efficacy was strongly represented: 41% scored high, demonstrating belief in their ability to manage competitive challenges, while 17% showed moderate levels.

In terms of perceived achievement, nearly half of the athletes (48%) expressed high satisfaction with their sports accomplishments, whereas smaller groups reflected either moderate (17%) or lower satisfaction (10%), indicating ambition for further growth or partial dissatisfaction.

The analysis of facade tendencies revealed that many athletes are concerned with image management. Thirty-eight percent scored high on self-presentation, suggesting a tendency to project a favorable, sometimes exaggerated, image, while 24% reported moderate scores. Self-deception was also evident, with 15% achieving maximum values and 19% showing moderate-to-high levels, pointing to an optimistic self-evaluation of abilities.

For self-presentation specifically, over half of the players expressed moderate-to-high concern with how they are perceived, a trait potentially beneficial in competitive contexts. Conversely, exaggeration received low scores in most cases (72% scoring 1–3), indicating responsibility and commitment to team tasks without seeking excessive recognition.

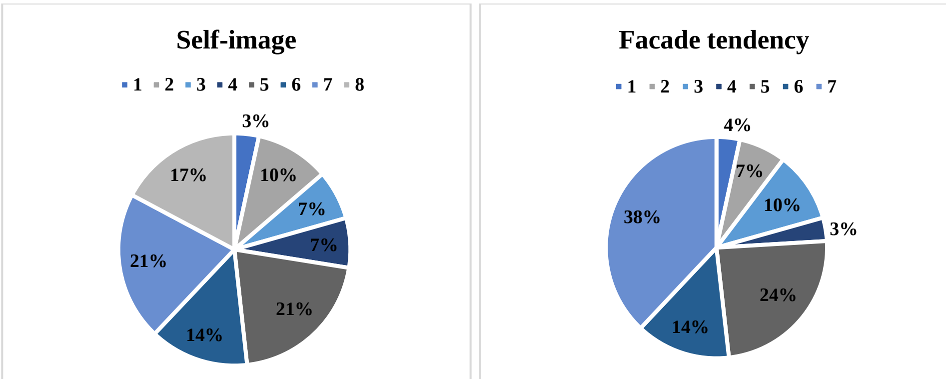


Fig. 3. Frequency of responses for size (a) self-image; (b) facade tendency

The analysis of self-depreciation shows that most senior rugby players avoid negative self-evaluation, with 72% reporting low scores (1–3). This suggests a healthy self-perception, protective of both mental health and athletic performance. Similarly, low regret scores (72%) indicate that players are not strongly burdened by past experiences, maintaining a forward-looking mindset beneficial for competition.

Gratitude was also prominent, as 66% of athletes reported low scores (1–3), reflecting a strong sense of thankfulness toward others' support. Only a minority demonstrated moderate levels of gratitude (10%), indicating variability in how athletes acknowledge external contributions to their success.

Integrity-related traits emerged as particularly strong. A large majority scored high on integrity (76%), sincerity (86%), honesty (83%), and morality (90%), underlining the importance of respect, fairness, and authenticity in rugby. These values appear deeply ingrained in the players' mindset, reinforcing both individual conduct and collective cohesion essential for team sports.

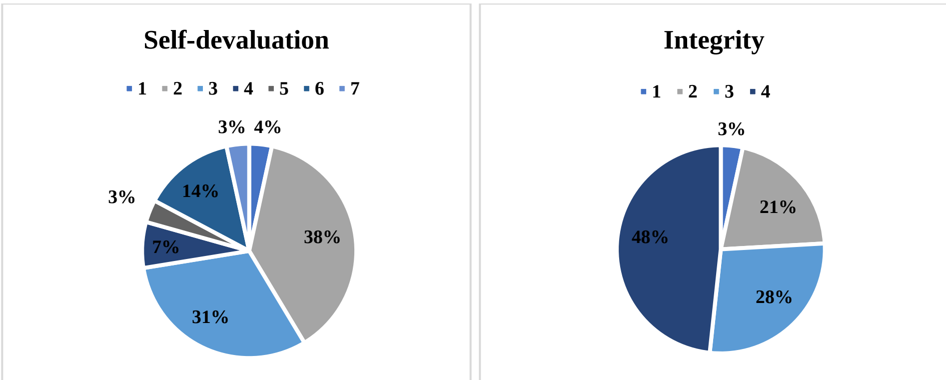


Fig. 4. Frequency of responses for size (a) self-devaluation; (b) integrity

Hypothesis testing 2

Junior rugby player

The normality of the data distribution was assessed using the Kolmogorov–Smirnov test for club players and the Shapiro–Wilk test for players from the Romanian national junior team. To identify differences in the psychological characteristics evaluated between club and national team junior players, the nonparametric Mann–Whitney U test was applied (Table 1), as the data distribution was not normal.

Table 1 presents a comparison between club and national team junior players in terms of self-perception, facade tendencies, self-depreciation, and moral integrity. Differences between group scores were not statistically significant ($p > 0.05$).

National team players exhibited a more positive self-image and lower tendencies toward self-depreciation, which may reflect experience gained at higher competitive levels. Facade tendencies were slightly higher among national team players, but differences were not significant, indicating similar social presentation strategies across groups.

Gratitude was higher among club players, while regrets and self-depreciation were similar between the two groups. Specifically, gratitude was slightly higher in club players (M = 3.5) compared to national team players (M = 2.8), but the difference was not statistically significant (p = 0.199). Regret levels were nearly identical between groups (p = 0.824), suggesting that both club and national team players have similar levels of decision reassessment. Self-depreciation was also similar (p = 0.713), indicating comparable levels of self-criticism across both groups.

Moral integrity was more pronounced among national team players, reflecting greater concern for ethics and fair play. Sincerity and honesty were similar across groups, suggesting that these values are consistently maintained among all players. Morality was stronger in national team players, who scored significantly higher (M = 6.7) compared to club players (M = 5.4), with the difference reaching statistical significance (p = 0.021), indicating a heightened commitment to rule adherence and ethical principles.

Table 1. Analysis of self-perception and attitude among club players and those who are part of the Romanian national junior team - nonparametric Mann–Whitney U test

		M	MR	P
SELF-IMAGE	Club players	7,2	33,11	0,283
	National team	7,7	39,03	
Self-esteem	Club players	5,8	33,63	0,506
	National team	6,2	37,31	
Self-efficacy	Club players	5,6	33,71	0,540
	National team	5,8	37,06	
Achievement	Club players	5,3	33,49	0,442
	National team	5,8	37,78	
FACADE TENDENCY	Club players	6,5	33,88	0,632
	National team	7,1	36,53	
Self-deception	Club players	5,5	33,53	0,458
	National team	5,9	37,66	
Self-presentation	Club players	3,9	33,20	0,322
	National team	4,4	38,72	
Exaggeration	Club players	4,3	35,39	0,497
	National team	4,0	31,59	
SELF-DEVALUATION	Club players	3,9	35,41	0,480
	National team	3,3	31,53	
Gratitude	Club players	3,5	36,17	0,199
	National team	2,8	29,06	
Regret	Club players	3,4	34,79	0,824
	National team	3,3	33,56	
Self-deprecation	Club players	3,3	34,98	0,713
	National team	3,0	32,94	

		M	MR	P
MORAL INTEGRITY	Club players	6,6	32,27	0,088
	National team	7,7	41,75	
Sincerity	Club players	5,2	32,05	0,059
	National team	6,1	42,47	
Honesty	Club players	5,1	34,20	0,820
	National team	5,3	35,47	
Morality	Club players	5,4	31,48	**0,021**
	National team	6,7	44,31	

M=mean; MR=mean rank; p=p value

Senior rugby player

The normality of the data distribution was assessed using the Shapiro–Wilk test for both club players and players from the Romanian national team.

For senior rugby players, to highlight differences in psychological characteristics between club and national team players, two statistical tests were applied. For the exaggeration facet, where the data distribution was normal, the Independent-Samples T Test was used (Table 2).

Analysis of the exaggeration facet indicates that national team players (M = 4.44) tend to have a more idealized perception of their own performance compared to club players (M = 3.73), which may be influenced by their experience in international competitions. However, the difference was not statistically significant, suggesting that the tendency to exaggerate is similarly present among club players (Table 2).

Table 2. Analysis of the exaggeration subscale between club players and those who are part of the Romanian senior national team - Independent-Samples T Test

		M		SD	p
Exaggeration	Club players	3,73	±	2,24	0,315
	National team	4,44	±	1,54	

M=mean; SD=Std. dev.; p=p value

The analysis of other psychological parameters was conducted using the nonparametric Mann–Whitney U test, as the data distribution was not normal.

National team players exhibited a more positive self-image, which may be explained by their greater competitive experience and higher performance level. The difference was statistically significant (p = 0.004), suggesting that selection and participation in international competitions contribute to increased self-confidence (Table 3).

Members of the senior national team were less prone to self-depreciation, providing a psychological advantage in competition. Club players were slightly more self-critical (M = 3.27) compared to national team players (M = 3.22), which may affect their performance and motivation.

National team athletes perceived themselves as having higher achievement levels, with differences between groups being statistically significant (p = 0.001). This perception may motivate greater engagement in training and competitions and is likely influenced by access to international competitions and recognition of performance (Table 3).

The facade tendency dimension was higher among national team players, suggesting greater concern for public image. Regarding moral integrity, the mean score was higher for national team players, indicating a stronger commitment to fair-play values. Differences between groups in these two dimensions were not statistically significant (p = 0.294 and p = 0.290, respectively) (Table 3).

Table 3. Analysis of self-perception and attitude among club players and those who are part of the Romanian senior national team - nonparametric Mann–Whitney U test

		M	**MR**	**P**
SELF-IMAGE	Club players	6,00	9,23	**0,004**
	National team	8,28	18,53	
Self-esteem	Club players	5,27	10,23	**0,015**
	National team	6,94	17,92	
Self-efficacy	Club players	6,36	13,05	0,312
	National team	6,78	16,19	
Achievement	Club players	6,45	8,36	**0,001**
	National team	7,94	19,06	
FACADE TENDENCY	Club players	7,36	12,95	0,294
	National team	8,56	16,25	
Self-deception	Club players	7,45	18,91	**0,039**
	National team	6,17	12,61	
Self-presentation	Club players	5,18	14,32	0,729
	National team	5,28	15,42	
SELF-DEVALUATION	Club players	3,27	17,05	0,290
	National team	3,22	13,75	
Gratitude	Club players	2,91	13,59	0,478
	National team	3,50	15,86	
Regrets	Club players	3,36	18,32	0,092
	National team	2,50	12,97	
Self-deprecation	Club players	2,64	16,91	0,322
	National team	2,22	13,83	
MORAL INTEGRITY	Club players	9,36	16,23	0,513
	National team	9,11	14,25	
Sincerity	Club players	7,36	15,45	0,806
	National team	7,28	14,72	

		M	MR	P
Honesty	Club players	7,18	14,05	0,604
	National team	7,39	15,58	
Morality	Club players	7,64	17,27	0,211
	National team	7,28	13,61	

M=mean; MR=mean rank; p=p value

DISCUSSION

The results confirm generally high levels of self-perception and self-confidence among Romanian female Rugby Sevens players, with differences between juniors and seniors influenced by competitive experience and psychological maturity. Junior players demonstrated strong motivation and positive self-esteem, though some showed a tendency toward idealized self-image, suggesting the need for targeted psychological support. Senior athletes exhibited more balanced self-perception and stronger moral integrity, reflecting advanced psychological development.

It should be emphasized that few studies have explored self-confidence and self-perception among female rugby players, particularly across age categories and within the Romanian context. This scarcity of research highlights the exploratory and original nature of the present study.

CONCLUSIONS

This study revealed generally high levels of self-perception and self-confidence among female Rugby Sevens players, emphasizing the crucial role of psychological factors in athletic performance. Differences between club and national team players confirm the positive influence of competitive experience on self-image and perceived achievement. Given the limited research in this area, especially in Romanian rugby, further studies are recommended to explore psychological dimensions such as self-efficacy and mental resilience among female athletes.

The analysis of questionnaire responses indicates a generally high level of motivation and engagement among junior rugby players. Moral integrity emerged as a defining dimension, reflecting a culture of fair play and respect consistently internalized by athletes. Rugby fosters strong ethical principles, integrity, sincerity, honesty, and morality, which are well established among both junior and senior players.

National team juniors showed a more positive self-image and higher self-efficacy, suggesting greater confidence in their abilities. Slightly higher facade tendencies indicate increased concern for public image, while club players reported more gratitude but also greater self-depreciation, implying a stronger need for external validation. Moral integrity was more pronounced among national team players, suggesting that exposure to international competition strengthens fair-play values and responsibility. The tendency to exaggerate was also higher among national team members, possibly reflecting the pressure and expectations of elite performance, whereas lower self-depreciation scores indicate better stress management and self-confidence.

AUTHOR CONTRIBUTIONS

All authors have equal contribution.

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THE RELATIONSHIP BETWEEN THE *DECISION-MAKING PROCESS* AND *ACHIEVEMENT MOTIVATION* AMONG THE HIGH SCHOOL STUDENTS INVOLVED IN TEAM BUILDING ACTIVITIES WITHIN PHYSICAL EDUCATION AND SPORT CLASSES

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ABSTRACT. *Introduction*: The integration of team building activities into Physical Education and Sports classes represents an essential tool for the socioemotional and motivational development of young people within the school environment. *Objective:* The objective of this research study was to analyse the relationship between emotion-based decision-making and achievement motivation among high schoolers participating in team building activities integrated into Physical Education and Sports classes. *Material and Methods*: The study involved 50 high school students, both female and male. By administering two questionnaires from the field of *personality* assessment ("Emotion-Based Decision-Making" and "Achievement Motivation"), meant to analyse emotion-based decision-making and achievement motivation, we evaluated the relationship between these two dimensions. To obtain the representation of the association between them, we used Pearson's correlation coefficient. We performed data processing and statistical analysis using SPSS software, version 20. *Results*: We found a significant positive correlation between emotion-based decision-making and achievement motivation among students ($r = 0.453$, $DF = 48$, $p < 0.001$). Our findings indicate that students participating in team building activities during School Physical Education classes display a decision-making process influenced by emotional factors and prove a strong desire for achievement. This aspect highlights a correlation between the emotional side of decision-making and individual motivation. Consequently, a higher degree of emotional involvement in decision-making correlates with increased individual motivation for achievement and personal satisfaction. *Discussion*: To underscore similarities and differences, the findings

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of this research study were compared with data from the literature addressing the relationship between emotions and the educational process in school physical activities, as reported, for instance, in the study titled *"Emotions–Decision-Making in Sport: Theoretical Conceptualization and Experimental Evidence"* published by Gershon Tenenbaum, Itay Basevitch, Lael Gershgoren, and Edson Filho in 2013. *Conclusions:* The research study has demonstrated that team building activities play an essential role in developing the socio-emotional competencies of high school students, thus allowing a better management of emotions in the decision-making process and supporting their motivation for achievement.

Keywords: decision-making process; achievement motivation; high school; team building; personality.

INTRODUCTION

In daily life, the term *motivation* is often used to explain why a person acts in a certain way. Motivation represents the underlying force that drives human behaviour. Whenever a need arises, it generates a reason which, in turn, directs an individual's behaviour towards attaining a specific goal. A person strives to reach that goal in order to preserve their internal balance or homeostasis (Harackiewicz et al., 1997). Achievement motivation reflects the individual's desire to excel in a specific task or activity. It is an acquired tendency that can be significantly cultivated and consolidated through adequate interventions (Baloria, 2018).

Achievement motivation was extensively studied by David Clarence McClelland, an American psychologist renowned for his contributions to the field of motivational psychology. This form of motivation can highly influence the way a person approaches assigned tasks, thereby increasing the desire to become competent and effective (Harackiewicz et al., 1997). Achievement motivation represents one of the most intensely analysed topics in current research conducted in the field. As previously mentioned, cultivating this form of motivation from the first years of school is essential because it represents an acquired tendency that can be developed and reinforced through early educational experiences. In this respect, Brier (2006) describes a series of activities meant to stimulate achievement motivation among students (Brier, 2006). Numerous studies have highlighted that a high level of performance motivation has a positive impact on academic performance, personal efficacy, and subjective well-being in general. Spinath, Spinath, Harlaar, and Plomin (2006) state in their study that performance motivation constitutes a prerequisite for success in both the academic field and sports and professional contexts (Spinath et al., 2006).

Team building activities

Team building has been defined as a method for a group to increase its efficiency, respond to the needs of its members, or improve working conditions (Brawley & Paskevich, 1997). According to the writings of Carron and collaborators (Carron & Spink, 1993; Carron, Spink & Prapavessis, 1997), team building interventions have focused on improving group cohesion. Specifically, cohesion refers to the extent to which the members of a group are united in accomplishing instrumental tasks and/or social activities (Carron, Brawley & Widmeyer, 1998).

A central principle in designing team building interventions meant to consolidate cohesion is that when team members manage to build a sense of unity or belonging, that sense acts as a catalyst for individual motivation. Thus, it directs the members' efforts towards achieving common objectives and improving collective performance (Carron et al., 1985; Carron, 1997; Martin, Carron, & Burke, 2009; Beauchamp, McEwan, & Waldhauser, 2017).

The decision-making process and its relationship with achievement motivation in the context of team building activities

Participation in school sports activities involves cooperation and efficient coordination (Carron, 2002) among several members over an extended period. The performance of a team depends on the individual proficiency of the students, their capacity to collaborate (Stevens & Bloom, 2003), and their ability to make rapid and effective decisions in dynamic contexts and show a genuine desire for achievement. In this regard, team building activities have been acknowledged as effective strategies for optimising team functioning, thus fostering cohesion, collective motivation, and decision-making processes (Martin, Carron & Burke, 2009).

Team building, through its structured activities, provides a favourable framework to cultivate the spirit of collaboration, clarify team roles, and stimulate achievement motivation among its members. Participation in such programs can improve students' ability to communicate effectively, make decisions under pressure, and adjust their personal objectives to those of the group. Therefore, team building becomes not only a tool to build cohesion, but also a means through which achievement motivation and the decision-making process can be consolidated in order to attain collective performance.

The analysis of the relationship between achievement motivation, decision-making, and team building interventions in school sports activities provides deeper insight into the way in which individual motivational dynamics integrate into the mechanisms of a group. This perspective offers a solid foundation for the investigation of the psychological factors involved in the efficiency and success of teams in the world of sports (Kwon, 2024).

The objectives of this research study

This study *aims* to analyse the relationship between the emotion-based decision-making process and achievement motivation among high school students who participate in team building activities integrated within Physical Education and Sports classes. Moreover, based on our findings, we envisage developing and proposing a set of team building activities designed to enhance decision-making skills and achievement motivation, thus providing teachers with a series of applicable methods for Physical Education and Sports classes.

To achieve this *objective*, the study was structured into two complementary phases. The first phase was dedicated to evaluating and observing the students' decision-making behaviour in the context of attending team building activities integrated into Physical Education and Sports classes. Our goal for this phase was to point out how emotions influence decision-making. The second phase assessed the relationship between achievement motivation and the decision-making process by analysing the participants' behaviour and performance during group activities. In addition, we measured the relevant motivational and emotional indicators and further investigated these relationships using statistical correlations.

Through this approach, the research aims to underline the connections between personal motivation, emotion management, and decision-making processes in educational and sports contexts. Thus, we want to offer a deep understanding of the factors that influence students' performance and engagement in team building activities.

MATERIAL AND METHODS

The *purpose* of the study was to analyse the relationship between the emotion-based decision-making process and achievement motivation among high school students participating in team building activities integrated into Physical Education and Sports classes. The objective of our study relies on several aspects. The literature (Miller & Byrnes, 2001) suggests that self-regulation and social values play a significant role in the decision-making process of adolescents, thus influencing their behaviours in social contexts. In this respect, we can effectively assess the relationship between the decision-making process and achievement motivation by collecting data directly from the participants in specific contexts of group activities, such as team building activities. Hence, we can observe and evaluate the interactions and the way in which emotions and motivation influence decision-making.

Secondly, few studies thus far have examined this relationship among high school students involved in team building activities. Therefore, this research aims to highlight the correlation between the two constructs and propose exercises applicable in Physical Education and Sports classes.

Thirdly, the evaluation of the decision-making process and of achievement motivation among high school students can be influenced by the specific context of team building activities. In addition, cultural and social factors (i.e., group norms and personal values) play an essential role in how teenagers make decisions and show their motivation for achievement. The literature supports this perspective: the motivational decision-making model proposed by Wentzel (2021) integrates beliefs related to competence and task values to explain students' behaviour within group activities; the systematic review conducted by Wang, Guo, and Degol (2019) highlights the cultural differences and the impact of sociocultural factors on motivation and academic performance. From the same standpoint, Kim's study (2015) reports how the specific context influences adolescents' achievement goal orientations. Based on this evidence, adding elements that reflect group dynamics and students' values can improve the validity of observations and enable more effective team building activities that stimulate both decision-making skills and achievement motivation.

Bases on the findings within our study, we aim to design and propose a range of team building activities promoting both decision-making skills and achievement motivation, thus providing teachers with a set of applicable methods within Physical Education and Sports classes.

Our *hypothesis* relied on the idea that the relationship between the decision-making process and achievement motivation among high school students is influenced by the specific context of team building activities. We assumed that cultural and social factors, such as group norms and personal values, play a significant role in decision-making and motivation display, according to the study carried out by Kim (2015), the review by Wang, Guo, and Degol (2019), and the motivational decision-making model of Wentzel (2021). This hypothesis aligns with the objective of the study: to analyse how group dynamics influence decision-making behaviour and achievement motivation, in order to propose an effective set of team-building activities adapted for students.

Participants

To ensure a balanced gender and age representation, we used a sample comprising 50 high school students, including both female and male participants, involved in team building activities conducted during Physical Education and Sports classes. A structured questionnaire was applied to collect data regarding the participants' decision-making process and achievement motivation.

From an initial sample of 200 participants, only 50 fully completed the questionnaire; they represented the final sample of the study.

The characteristics of the participants were as follows:

• *Age* (N = 50): 15–17 years old, with a mean of 16.52 and a *standard deviation* of 0.838.

• *Gender*: 27 girls (54%) and 23 *boys* (46%).

• *Level of engagement in team building activities*: all participants took part in at least one activity during Physical Education and Sports classes.

• Instruments applied: questionnaires within the "personality" field regarding the decision-making process - "*Emotion-Based Decision-Making*" and achievement motivation – "*Achievement Motivation*."

The level of involvement in *team building* activities was assessed through self-reporting, and all participants completed questionnaires on the decision-making process and on achievement motivation. We found considerable diversity within the sample regarding the classes and their level of experience in group activities.

Measuring

Two questionnaires within the "personality" field were applied - *Emotion-Based Decision-Making* and *Achievement-Seeking* - to evaluate emotional decision-making and achievement motivation. Firstly, we used the *Emotion-Based Decision-Making* scale, part of the *Personality* domain (IPIP) and the subdomain titled *Seven Components Potentially Related to Emotional Intelligence* (Barchard, 2001). The scale contains nine items and measures decision-making autonomy (i.e., an individual's likelihood to make independent decisions). It was translated and adapted into Romanian by Dragoș Iliescu (cultural adaptation level 2), based on the *International Personality Item Pool* (Goldberg et al., 2006; Iliescu et al., 2015).

Among the nine items, four measured the student's tendency to make decisions based on affective (emotional) factors, three assessed the propensity to be guided by intuition, inspiration, and creativity, and two evaluated the likelihood of relying on rational thinking and objective analysis in making important decisions.

Furthermore, we included the main factors within the *Achievement-Seeking* scale, part of *Tellegen's Multidimensional Personality Questionnaire (MPQ)*, from the ResearchCentral.ro database. This scale measures achievement motivation, namely the student's tendency to set personal goals and make sustained efforts to attain them. The scale comprises ten items and was translated and adapted into Romanian by Dragoș Iliescu (cultural adaptation level 2), based on the *International Personality Item Pool* (Goldberg et al., 2006; Iliescu, Popa & Dimache, 2015; Lang et al., 2006).

Among the ten items in the questionnaire, two measure the students' tendency to make additional efforts to achieve their goals, highlighting achievement motivation and responsibility. Two items measure the tendency to be persistent and responsible in completing tasks. One item measures the tendency to be active, involved, and motivated to use leisure time for personal achievements or development, reflecting performance motivation and organisational skills. One item measures the tendency to make only minimal efforts to achieve one's goals, indicating a pragmatic or efficiency-oriented motivational style. Two items measure the tendency to show moments of lacking initiative or motivation, reflecting passivity or relaxation. One item measures the likelihood of postponing or avoiding the initiation of activities, thus highlighting difficulties in self-regulating effort. Another item measures the tendency to depend on external incentives to begin activities, therefore indicating a low self-motivation level.

The items were formulated in language accessible to students and evaluated on a six-point Likert scale (from 1 - "Strongly disagree" to 6 - "Strongly agree").

To represent the relationship between the two dimensions, we used Pearson's correlation coefficient. Data processing and statistical analysis were carried out using the SPSS software, version 20.

Procedure

The study was conducted in schools among high school students, with approval obtained from the school administration and the Physical Education and Sports teachers. The potential participants were informed about the purpose of the research, which was to investigate the relationship between the decision-making process and achievement motivation among high school students involved in team building activities during Physical Education and Sports classes. They were also informed about the confidentiality of their answers. The students were asked to provide informed consent for participation, and in the case of underage participants, parental consent was also obtained. Before completing the scale, the participants attended a team building activity program conducted during Physical Education and Sports classes. The average time necessary to fill out the scale was approximately 30 minutes. At the end, the students completed a demographic questionnaire, which included information regarding age, gender, previous involvement in team building activities, and their general level of participation in Physical Education and Sports classes.

RESULTS

Descriptive statistics

To provide a general overview of the scores obtained, we calculated the mean, standard deviation, minimum, and maximum values for each variable: *emotion-based decision-making* and *achievement motivation*. This analysis enabled us to point out the central level and the variability of the scores within the sample.

Table 1. Descriptive statistics of the scores for the study variables
Emotion-based decision-making

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
LD_TOTAL	50	19.00	53.00	36.5800	.99595	7.04241
Valid N (listwise)	50					

The results regarding *emotion-based decision-making* showed that, from a sample of 50 participants, the scores ranged between 19 and 53, with an *arithmetic mean* of 36.58 and *a standard error* of 7.04. The *standard error of the mean* was 0.996, indicating a precise estimation of the mean value for the entire sample.

Fig. 1. Descriptive statistics of the scores for the study variables
Emotion-based decision-making

Table 2. Descriptive statistics of the scores for the study variables
Achievement motivation

Descriptive Statistics

	N	**Minimum**	**Maximum**	**Mean**		**Std. Deviation**
	Statistic	**Statistic**	**Statistic**	**Statistic**	**Std. Error**	**Statistic**
LD_TOTAL	50	20.00	60.00	40.7000	.92549	6.54420
Valid N (listwise)	50					

The results regarding *achievement motivation* showed that, from a sample of 50 *participants*, the values ranged between 20 and 60, with an *arithmetic mean* of 40.70 and a *standard error* of 7.54. The *standard error of the mean* was 0.925, which shows an accurate estimation of the mean value regarding the entire sample.

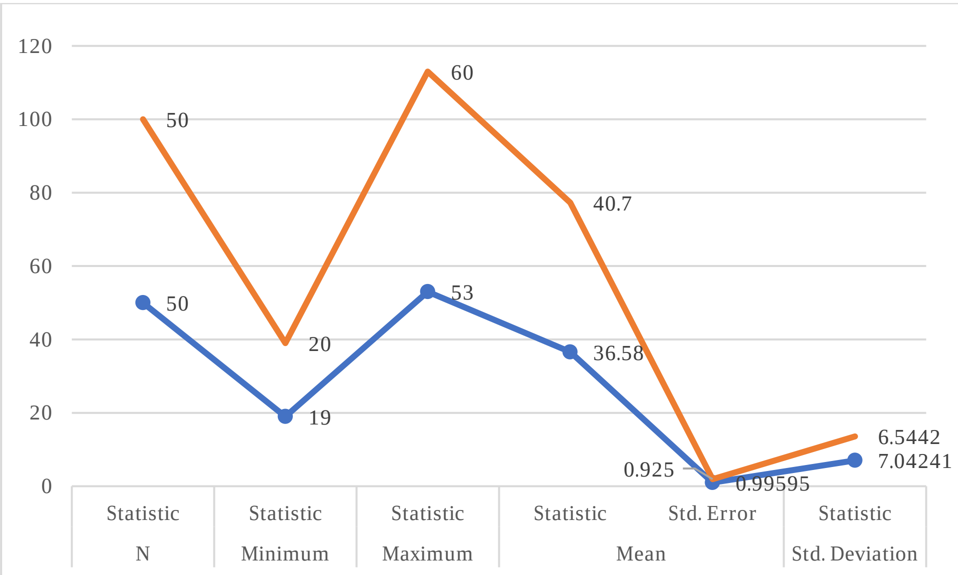

Fig. 2. Descriptive statistics of the scores for the study variables
Achievement motivation

Table 3. Descriptive statistics on the age of the participants

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
AGE	50	15.00	18.00	16.5200	.11863	.83885
Valid N (listwise)	50					

The age of the participants (N = 50) ranged from 15 to 18 years, with a mean of 16.52 years and a standard error of 0.84, indicating a relatively homogeneous age distribution within the sample.

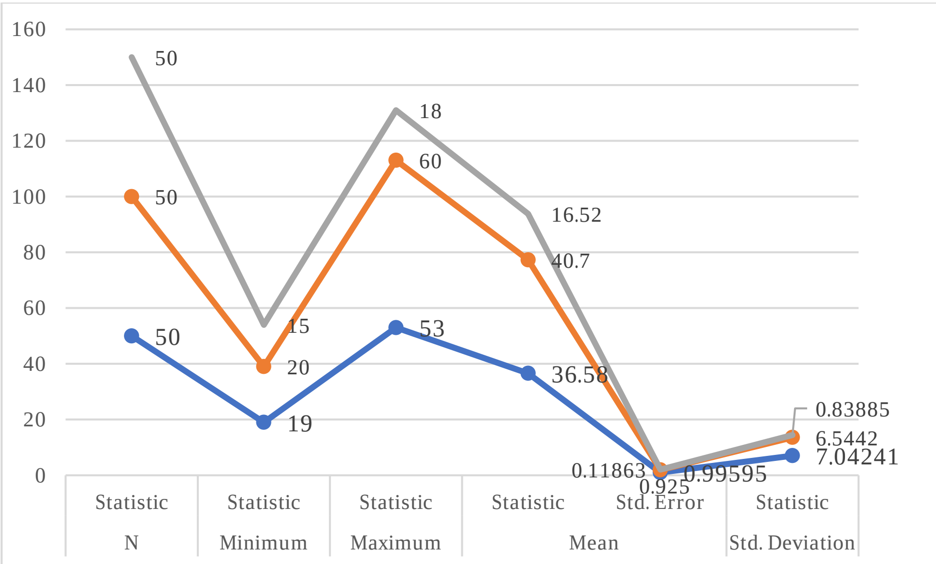

Fig 3. Descriptive statistics on the age of the participants

The correlation between emotion-based decision-making and achievement motivation

To investigate the relationship between *emotion-based decision-making* and *achievement motivation*, we calculated Pearson's correlation coefficient. This analysis enabled us to evaluate the degree and direction of the association between emotional involvement in the decision-making process and individual motivation for achievement among students attending team building activities during Physical Education and Sports classes.

Table 4. The correlation between emotion-based decision-making and achievement motivation

Correlations

		LD_TOTAL	DR_TOTAL
LD_TOTAL	Pearson Correlation	1	.453**
	Sig. (2-tailed)		.001
	N	50	50
DR_TOTAL	Pearson Correlation	.453**	1
	Sig. (2-tailed)	.001	
	N	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

We used Pearson's correlation coefficient to investigate the relationship between *emotion-based decision-making* and *achievement motivation*. The analysis highlighted a significant positive correlation between the two variables ($r = 0.453$, $DF = 48$, $p < 0.001$), indicating that the greater the degree of emotional involvement displayed by students in the decision-making process, the higher their motivation for personal accomplishments.

This finding suggests a close connection between the emotional components of the decision-making process and individual motivation. It stands to show that students who make decisions influenced by feelings and intuition are more likely to reach their set goals and actively engage in activities for their personal development.

In the context of team building activities carried out during Physical Education classes, these correlations show that emotional involvement can be a facilitating factor for achievement motivation, highlighting the importance of interactive and collaborative experiences in stimulating both decision-making and the personal performance of students.

DISCUSSIONS

To interpret our findings, we compared them with data in the literature on the correlation between emotions and the educational process in school physical activities. The results of this study are consistent with the findings of Tenenbaum et al. (2013), who highlight the central role of emotions in decision-making in sports contexts, with an impact on both the quality and the speed of decisions. Hence, students who make decisions guided by emotional factors display a stronger desire for achievement, emphasising the importance of emotional components in individual motivation.

In alignment with the studies of Lane and Terry (2000), which show that positive emotions increase motivation and performance in physical activities, our findings suggest that emotional involvement in decision-making can enhance students' motivation, especially within team building activities designed to provide interactive and stimulating contexts. In addition, the findings are consistent with the various research conducted by Carron et al. (2005), which reports that interaction and peer support in team activities improve emotional involvement and achievement motivation. This suggests that collaborative experiences help to consolidate students' motivation and engagement.

Moreover, the studies conducted by Gucciardi et al. (2011) indicate that emotional intelligence and self-regulation capacity influence success and engagement in various physical activities. The significant correlation found in our study between *emotion-based decision-making* and *achievement motivation* suggests that developing socio-emotional skills can be a determining factor in better academic performance and higher motivation among students during Physical Education and Sports classes.

SUMMARY AND CONCLUSIONS

Based on the initially formulated hypothesis and the findings obtained, we detailed several relevant conclusions regarding the relationship between the *decision-making process* and *achievement motivation* among high school students attending team building activities during Physical Education and Sports classes. These conclusions pinpoint how emotional factors influence individual motivation and the importance of an interactive educational context in promoting achievement motivation.

Data analysis underlined a *significant positive correlation* between emotion-based decision-making and achievement motivation among students ($r = 0.453$, $DF = 48$, $p < 0.001$), which indicates that a higher degree of emotional involvement in the decision-making process leads to an increase in their motivation to reach personal goals. This association suggests that emotional factors not only influence how students make decisions but also play a major role in stimulating achievement motivation and commitment to various educational activities.

Students who make decisions influenced by emotional factors show a stronger desire for achievement, which suggests that emotional involvement plays an essential role in individual motivation. This correlation highlights that, in the context of team building activities carried out during Physical Education classes, emotional factors not only model the decision-making process but also help to stimulate students' desire to reach their personal goals and actively engage in diverse educational experiences.

Our findings show that attending team building activities during Physical Education and Sports classes promotes both emotional involvement in the decision-making process and the students' motivation to achieve their goals. These data clearly prove the importance of an interactive educational context, where practical and collaborative experiences directly contribute to the development of socio-emotional skills and to the reinforcement of achievement motivation.

The results indicate that a higher degree of emotional involvement in decision-making is directly associated with increased motivation to attain personal goals and a higher level of personal satisfaction. In turn, it proves that emotions represent a facilitating factor in enhancing achievement motivation.

Our findings demonstrate that Physical Education and Sports teachers, along with school management, can integrate activities that encourage emotional reflection and decision-making, directly contributing to the consolidation of students' motivation and engagement within the educational process.

Finally, these findings suggest that future research should also investigate other variables that may influence the relationship between emotions and achievement motivation, such as personality traits, previous successful experiences, or the level of self-regulation. The goal is to get a better insight into the psychological mechanisms involved in these processes.

AUTHOR CONTRIBUTIONS

Conceptualisation, T.A.R., A.B.A., and D.M.I.; Methodology, T.A.R., A.B.A., and D.M.I.; Software, T.A.R. and A.B.A.; Validation, T.A.R., A.B.A., and D.M.I.; Formal Analysis, T.A.R. and D.M.I.; Investigation, T.A.R. and D.M.I.; Resources, D.M.I., A.B.A., and T.A.R.; Data Curation, D.M.I. and T.A.R.; Writing - Original Draft, T.A.R. and A.B.A.; Writing - Review and Editing, T.A.R. and A.B.A.; Visualisation, T.A.R. and D.M.I.; Supervision, T.A.R. and D.M.I.; Project Administration, T.A.R., A.B.A., and D.M.I. All authors have equal contributions. Each author contributed equally. All authors have read the final version of the manuscript and approved it for publication.

CONFLICT OF INTEREST

The authors did not identify any conflicts of interest.

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DIFFERENCES IN BODY COMPOSITION AND HANDGRIP STRENGTH AMONG 12–15-YEAR-OLD FOOTBALL PLAYERS FROM NORTHEASTERN ROMANIA

Florin-Petruț TROFIN[1,2*], Cezar HONCERIU[1,2]

ABSTRACT. *Introduction:* Early adolescence is marked by a series of anatomical and functional changes. Understanding these functional adaptations is particularly relevant for football coaches, as they influence training strategies and performance development. *Objective:* This study aimed to examine age-related differences in body composition parameters and handgrip strength among junior football players. *Materials and Methods:* Between September 2024 and August 2025, 151 male football players aged 12 (n=18), 13 (n=35), 14 (n=45), and 15 years (n=53) were assessed. Handgrip dynamometry is widely recognized in literature as a reliable measure of overall muscular strength in athletes. Two Constant hand dynamometers (model 14192-760E) were used, with participants performing maximal voluntary contractions while standing, arms fully extended and held obliquely laterally. *Results:* Significant anthropometric increases were observed between ages 13 and 14, whereas BMI remained consistent across age groups. Muscle mass increased from 39.06 ± 2.21% at age 13 to 41.09 ± 1.37% at age 14, while body fat percentage did not change significantly. No significant differences were observed in handgrip strength, despite notable changes in body composition. *Conclusions:* Handgrip strength assessment represents a practical tool for monitoring and evaluating muscular strength in adolescent athletes. The data provided by this study may serve as reference values for coaches in the region. In this cohort, early adolescence was associated with nonsignificant changes in handgrip strength, despite measurable alterations in body composition.

Keywords: handgrip strength; football; anthropometry; body composition; early adolescence.

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INTRODUCTION

During adolescence (11–16 years) substantial morphological, hormonal, and functional changes occur. These are evident in body mass, fat-free mass (FFM), muscle mass, and body fat. Functional adaptations follow, with strength increasing as chronological age advances.

Anthropometric transformations are particularly relevant in football, since they may influence not only physical performance but also injury risk, energy-use efficiency, and adaptation to competitive demands.

Assessment and monitoring of body composition in adolescent athletes have high practical and scientific importance. Likewise, knowledge of strength levels benefits athletic preparation, because associations exist between body composition and motor qualities. In particular, muscle mass and body fat affect running speed, explosive strength and endurance. Coaches and multidisciplinary sport-science staff can use monitoring of body composition and strength to individualize training and to prevent injuries (Leão et al., 2022).

Between 12 and 15 years, growth and development are characterized by large fluctuations. Height changes and endocrine events produce unpredictable performance outcomes for athletes who previously showed great promise in their pre-adolescent motor behavior. This implies the need to adapt football training plans; interpreting anthropometric data appropriately is key to the success of individualized interventions (Nikolaidis & Karydis, 2011).

Adolescents show marked variability in body-composition and strength indicators. Sources of this variation include chronological age, biological maturation, characteristics of sport training, and other factors. Physical-criteria selection in academies is therefore challenging and requires careful attention. An increase in strength with advancing age and biological maturation has been documented; handgrip strength is influenced by changes in body size and by maturation stage (Malina et al., 2004).

Recent studies have produced normative data for body composition and handgrip strength in adolescents from European and South American populations, though few studies have focused on Eastern Europe for the 12–15-year age range. Measurements of football players in U15, U17 and U19 categories revealed increases in muscle mass and moderate reductions in adipose tissue in the older age groups (Spehnjak et al., 2021).

Longitudinal cohort studies have shown that ongoing football practice reduces body-fat percentage and increases fat-free mass. This effect was observed in a sample of adolescent boys who achieved significant improvements after 12 months of regular training, accompanied by increases in handgrip strength (França et al., 2023).

Handgrip strength testing is simple and reliable, easy to administer, and requires less space and equipment compared with many other strength assessments. In youth, handgrip strength correlates with overall strength and with functional muscle quality. It is frequently included in junior test batteries because it correlates with various physical parameters such as isometric strength, speed, and lower-limb explosive power (Naimo & Gu, 2022).

Optimization of handgrip strength is associated with chronological age and biological maturation. A recent study examined relationships among handgrip strength, vertical and horizontal jump performance, sprint speed, chronological age and maturation. Strong associations were found with the first three performance measures and moderate associations with age and maturation. The sample comprised 221 football players aged 11–19 years (Schulz et al., 2025).

The importance of maturation was demonstrated in a study of U14 players in Brazil undergoing sports selection: compared with those who were not selected, the chosen athletes showed superiority in sexual maturation, salivary testosterone levels and handgrip strength (Massa et al., 2022).

Responses to strength-specific training vary with maturation stage and less so with the specific characteristics of the training program. For this reason, inclusion of anthropometric parameters in analyses of adolescents is recommended (Retzepis et al., 2025).

Biological maturation plays a major role in differentiating individuals of the same chronological age with respect to anthropometric components and aptitude-related traits. Implementation of strength programs in young athletes produces different outcomes depending on maturation stage (Peña-González et al., 2019).

Beyond mere participation in the sport, body composition and strength are affected by playing position, training frequency, training volume, and individual differences in biological maturation. Among players aged 14–15 years, differences have been observed in body mass, height, muscle mass, body fat and handgrip strength (Łuszczki et al., 2025).

Results obtained from a given geographic area can be used by sport and education specialists to seek optimal strategies for physical development of the adolescents they train (Oliver et al., 2023).

Although abundant normative references exist in the international literature, applying them to populations such as adolescents from north-eastern Romania may be problematic because training practices and socio-cultural or socio-economic characteristics can differ from those of the samples on which the published norms are based. Our study thus has practical value for coaches and teachers in the region by guiding training planning and talent identification at the local/regional level (Hermassi et al., 2023).

The present study aims to analyze the development of body composition and handgrip strength in football players aged 12–15 years from north-eastern Romania. Grouping of the athlete cohort is based on chronological age. The results may enrich local and regional reference data and provide coaches with information to refine training decisions grounded in sport monitoring.

Consistent with findings in the literature, our hypothesis is that, in adolescent football players from north-eastern Romania, body composition will change with increasing age between 12 and 15 years – specifically, an increase in muscle mass percentage and a decrease in body fat percentage – and that handgrip strength will increase with age.

MATERIAL AND METHODS

Participants

From an initial cohort of 212 boys, 151 were selected for assessment of body composition and handgrip strength. Inclusion criteria were: chronological age between 12 and 15 years, regular participation in football training, and geographic residence in north-eastern Romania. The selected athletes were registered with four sports clubs located in Iasi and Suceava counties. To examine age-related development, the sample was stratified into four age groups: 12-year-olds (n = 18), 13-year-olds (n = 35), 14-year-olds (n = 45), and 15-year-olds (n = 53). Their characteristics are summarized in Table 1.

The study protocol was approved by the Scientific Research Ethics Committee of the Faculty of Physical Education and Sport, Iasi (Approval No. 24/28.02.2023) and was conducted in accordance with the Declaration of Helsinki.

Procedure

During the 2024/2025 competitive season, participants were recruited and measured on-site at their respective clubs by an assessment team composed of students from the Selection and Sports Counseling Center, Faculty of Physical Education and Sport, Iasi. Each member of the research team received training prior to data collection.

The study variables comprised body-composition parameters (height, body mass, BMI, body fat, and muscle mass) and handgrip strength (dominant handgrip, nondominant handgrip, and mean handgrip).

Body composition was assessed using an OMRON BF-511 body composition analyzer (bioelectrical impedance). Height was measured barefoot on a horizontal surface prior to stepping onto the analyzer. A Handy60 electronic level with an attached Bosch GLM80 professional laser distance meter was used for the height measurement. After entering the participant's personal data (age, sex, and height) into the device, the subject mounted the body analyzer barefoot and was handed the analyzer's control unit, which they grasped with the hands in pronation. During the measurement the arms were extended forward with the hands positioned at shoulder level. When the measurement was complete, the values displayed by the device were recorded on the results form.

Handgrip strength was measured with two Constant hand dynamometers (Constant, Guangdong, China; model 14192-760E) using a squeeze/pressure mechanism. The grip span of each dynamometer was set at the midpoint. Each participant performed maximal voluntary grips simultaneously with both hands while standing, with the arms positioned obliquely at the sides and the palms facing forward. Each contraction lasted 3–5 seconds to allow attainment of the maximal value. Two trials were recorded, and the trial with the highest combined (summed) value from the two dynamometers was used for analysis.

All measurement sessions were audio-recorded to allow subsequent verification of the recorded results and to correct any transcription errors.

Data analysis

All data were entered into a Microsoft Excel database and subsequently exported to GraphPad Prism version 10.4.2 (GraphPad Software, Inc.) for analysis. Outliers were identified and removed using the ROUT method ($Q = 1\%$), resulting in the exclusion of $n = 8$ observations. The normality of the data distribution was then assessed. Between-group differences attributable to chronological age were examined for each anthropometric and strength parameter using one-way ANOVA. Where the ANOVA indicated a significant effect, Tukey's multiple-comparisons test was applied to identify pairwise differences between adjacent age groups (i.e., year-to-year comparisons). Statistical significance was set at $p < 0.05$.

RESULTS

Consistent with our study hypothesis, the data are presented in Table 1 for the four analyzed age groups. For each variable, the F statistic and significance level from the one-way ANOVA are reported.

Significant differences were observed for height ($F(3,147) = 26.97$, $p < 0.0001$), body mass ($F(3,147) = 18.26$, $p < 0.0001$), BMI ($F(3,141) = 5.11$, $p = 0.0022$), and muscle mass ($F(3,110) = 13.97$, $p < 0.0001$). In contrast, body fat ($F(3,110) = 1.99$, $p = 0.12$) and handgrip strength ($F(3,146) = 1.72$, $p = 0.166$) showed no significant differences between the age groups.

Table 1. Anthropometric characteristics and handgrip strength by chronological age

	12 years (n=18)	13 years (n=35)	14 years (n=45)	15 years (n=53)	F	p
Height (cm)	159.9±7.02	162.1±10.4	171.8±6.31	174.6±7.79	$F_{(3, 147)}$ = 26.97	<0,0001
Body mass (kg)	51.59±9.77	50.34±10.03	59.16±7.33	62.62±7.78	$F_{(3, 147)}$ = 18,26	<0,0001
BMI (kg/m2)	19.49±2.39	18.95±2.2	19.83±1.64	20.46±1.33	$F_{(3, 141)}$ = 5.11	0.0022
Body fat (%)	14.26±5.38	14.92±4.94	12.35±3.55	13.64±3.68	$F_{(3, 110)}$ = 1.99	0.12
Muscle mass (%)	39.45±2.5	39.06±2.21	41.09±1.37	41.73±1.53	$F_{(3, 110)}$ = 13.97	<0,0001
Dominant handgrip (kg)	33.79±18.66	27.55±12.66	32.09±5.91	31.86±6.2	$F_{(3, 147)}$ = 2.12	0.099
Nondominant handgrip (kg)	24.79±8.96	26.82±12.26	29.73±5.38	29.87±6.16	$F_{(3, 145)}$ = 2.45	0.066
Average handgrip (kg)	29.21±13.15	27.19±11.42	30.91±5.38	30.86±5.79	$F_{(3, 146)}$ = 1.72	0.166

*Significant differences, p< 0.05

Based on Tukey's multiple-comparisons test results, the pairwise differences between groups were plotted for each variable. Of primary interest were the significant year-to-year (adjacent-age) differences, although meaningful interpretations can also be drawn from the other observed changes.

Our results demonstrate anthropometric changes reflected by differences in height and body mass (Table 1). In Figure 1A there is a year-to-year increase

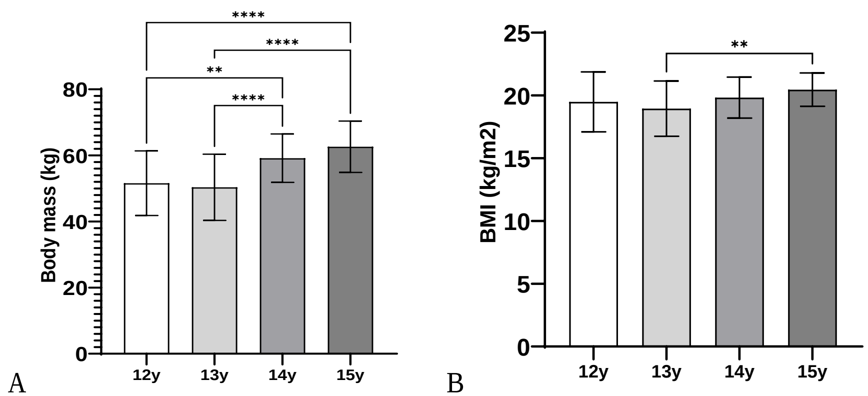
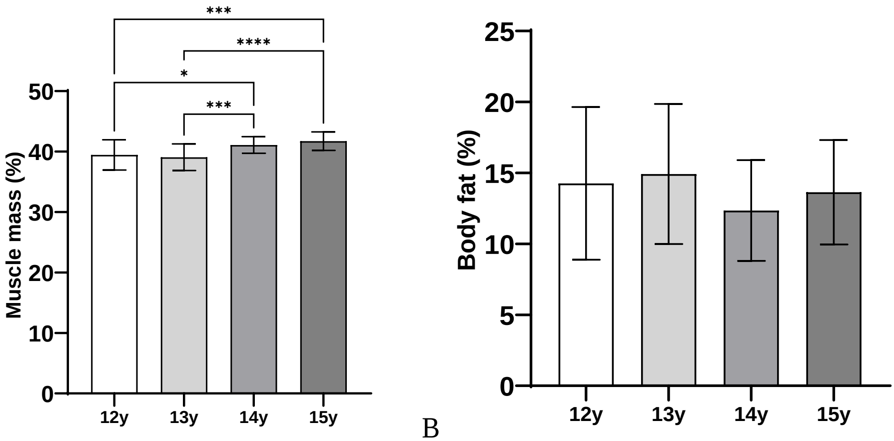


Fig. 1. Intra-individual changes between age groups for body mass (A) and BMI (B)

in body mass, with a significant change observed between 13 years (50.34 ± 10.03 kg) and 14 years (59.16 ± 7.33 kg). In Figure 1B, BMI changed only between 13 and 15 years ($p = 0.0011$); there was no progressive, linear effect of advancing age on BMI.

Consistent with the increases in body mass, percent muscle mass showed a marked rise during early adolescence (Figure 2A). Specifically, muscle mass increased from 39.06 ± 2.21% at 13 years to 41.09 ± 1.37% at 14 years; one-way ANOVA indicated a significant group effect ($F(3,110) = 13.97$, $p < 0.0001$), and post hoc comparisons identified the 13→14 year change as significant. By contrast, body-fat percentage displayed only minor fluctuations and remained essentially stable between 12 and 15 years (Figure 2B), in agreement with the non-significant ANOVA result for body fat ($F(3,110) = 1.99$, $p = 0.12$).



A B

Fig. 2. Intra-individual changes between age groups for muscle mass (A) and body-fat percentage (B)

Handgrip strength remained relatively unchanged across the four age groups. On the dominant side (Figure 3A), results showed inconsistency, a trend that was also observed in the overall average of both hands (Figure 3C). In contrast, the non-dominant hand (Figure 3B) exhibited a moderate increase in mean strength, from 24.79 ± 8.96 kg at age 12 to 29.87 ± 6.16 kg at age 15. However, these differences did not reach statistical significance ($F(3,146) = 1.72$; $p = 0.166$).

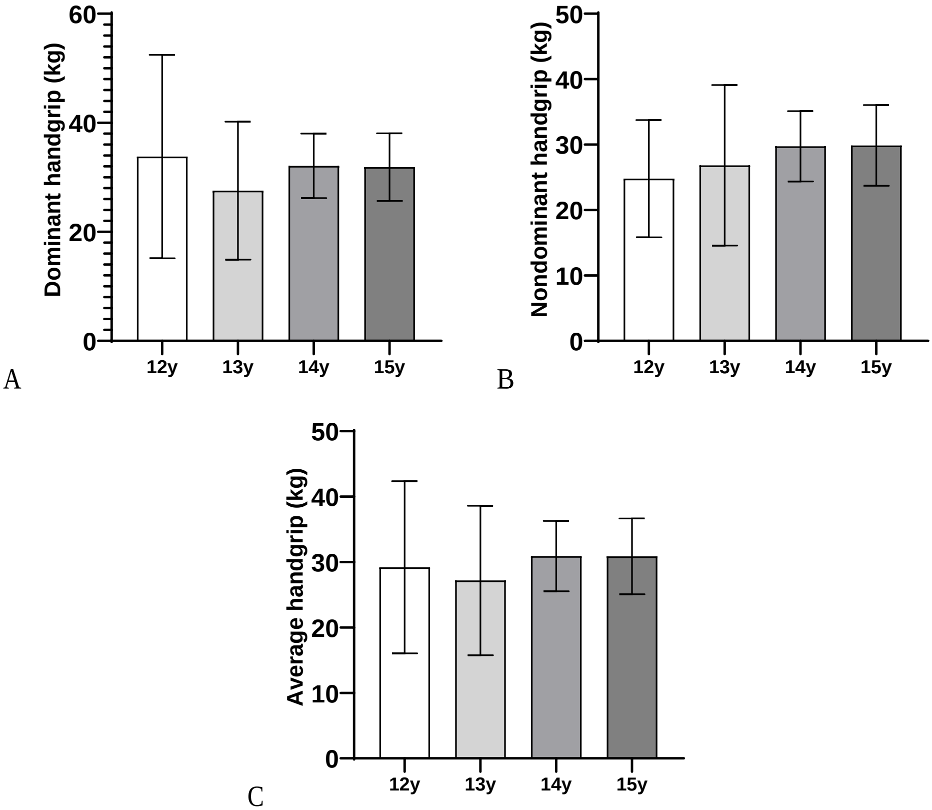


Fig. 3. Intra-individual changes between age groups for dominant (A), non-dominant (B), and average handgrip strength (C)

DISCUSSION

Our study aimed to analyze the effect of chronological age on body composition parameters and handgrip strength among adolescent football players. The reported data have practical relevance for coaches and physical education teachers involved in monitoring and optimizing the physical development of young athletes.

The results indicate that body mass increases in parallel with a rise in the percentage of muscle mass. Chronological age significantly influences these changes, particularly during the transition from 13 to 14 years of age, suggesting that this stage represents a key point in somatic and functional development.

Other variables remained unchanged, providing only partial support for our initial hypothesis. Although most parameters showed fluctuations in value, the mean non-dominant handgrip strength followed an upward trend. However, this progression was not sufficient to reach statistical significance.

Body Composition

The observed increases in height and body mass among participants aged 12 to 15 years are consistent with trends reported in previous studies. This developmental pattern reflects the pubertal growth spurt, during which rapid somatic and physiological changes occur. Such transformations help explain the fluctuations often seen in adolescents' physical performance. Malina et al. (2004) reported that players aged 13–15 years exhibit considerable variation in functional capacity, largely due to the influence of biological maturation and anthropometric changes.

Changes in BMI across age groups are closely related to the combined effects of body mass and height increases. Among adolescent athletes, this progression is common; however, BMI alone provides limited insight into body composition and should be interpreted alongside additional indicators. Leão et al. (2022) demonstrated that in youth athletes, isolated BMI assessment is insufficient for accurately describing body composition.

Spehnjak et al. (2021) observed that U15 players exhibited increases in fat-free mass percentages, accompanied by stable or slightly reduced body fat levels. Consequently, an upward change in BMI cannot be attributed solely to increased adipose tissue.

The lack of statistically significant differences in body fat percentage among the four age groups may be explained by individual variability in biological maturation. Regular football training has been associated with reductions in body fat, although such effects typically emerge over longer time frames. Spehnjak et al. (2021) also noted that while consistent participation in training tends to decrease adipose tissue, individual variability remains high.

The cross-sectional design of the present study and the diverse training regimens of participants may have contributed to the absence of significant changes in fat percentage. A longitudinal approach could more effectively capture the influence of chronological age on body composition. Additionally, the electrical bioimpedance method used in this study is sensitive to hydration status—a factor that, although communicated to participants, could not be fully controlled by the research team.

In older age groups (U15–U17), a gradual decline in body fat percentage has been reported, although differences remain small and population-dependent. The proportional increase in both height and fat-free mass may result in the relative stability of body fat levels observed in younger football players (Spehnjak et al., 2021).

Consistent with previous findings, muscle mass demonstrated an expected increase, primarily driven by the physiological changes associated with puberty and the physical demands of football training. Positive correlations have been identified between increased muscle mass and indices of strength and power among youth players in the U14 and U15 categories (Leão et al., 2022).

Handgrip strength

Handgrip strength did not change significantly across the studied age groups, a finding that aligns with parts of the existing literature emphasizing the predominant role of biological maturation over chronological age. Gómez-Campos et al. (2018) demonstrated that differences in handgrip strength among adolescents are more strongly influenced by the level of biological maturation than by chronological age itself.

There is a well-established congruence between muscular development and the accumulation of fat-free mass during adolescence, reflecting the physiological transformations that accompany growth and maturation. Konarski et al. (2024) identified height, body mass, fat-free mass, and skeletal maturation as major predictors of strength development when age was considered as the independent variable (Konarski et al., 2024).

Another important consideration concerns the specificity of the sport. Disciplines that involve frequent gripping actions—such as climbing or gymnastics—demonstrate clear differences in handgrip strength across age categories. Since football is a sport in which upper-limb muscular engagement is relatively limited, greater variability in handgrip strength may be expected among players. Moreover, the lack of targeted upper-body and forearm training in certain geographic regions could also explain the modest progression observed in this parameter.

Given the strong correlation between handgrip strength and overall muscular strength, its interpretation should be contextualized within the broader framework of total muscle mass and training specificity (Abe et al., 2024; Jansson et al., 2025).

CONCLUSIONS

The results of our study reveal particular trends when compared with existing literature. In certain aspects—such as body mass and muscle mass—our findings align with the general growth and developmental patterns observed among adolescent athletes. However, the remaining parameters, although initially expected to follow an upward trajectory, displayed stagnation and fluctuations consistent with the physiological variability characteristic of the 12–15 age interval.

The group of adolescent male football players partially confirmed our hypothesis through significant changes in body mass and muscle mass, with a clear threshold of growth observed between ages 13 and 14. Other anthropometric and strength-related variations may be attributed to differences in biological maturation, which appear to exert a stronger influence than chronological age. Among adolescent boys, chronological age does not represent a reliable indicator of physical development. Consequently, handgrip strength does not seem to be directly influenced by age progression, reflecting instead individual maturation patterns and sport-specific physical demands.

Considering the relatively small sample size and limited age range, the data presented here may still hold practical relevance for coaches and physical education professionals in northeastern Romania. Handgrip strength can be easily assessed and provides valuable information that can be integrated into athletic training programs.

Given the current context in which Romanian football faces challenges on the international stage, we emphasize the need for a multilateral physical preparation approach. Developing overall strength capacities may enhance competitiveness and contribute to improved athletic performance among young Romanian football players.

AUTHOR CONTRIBUTIONS

Florin-Petruț TROFIN and Cezar HONCERIU contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

No conflict of interest.

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