

## Effects of a Four-Week Climbing Intervention on Motor Abilities in PE Class

Béla József BALLA<sup>1\*</sup>, István FINTA<sup>2</sup>, Iuliana BOROS-BALINT<sup>3</sup>

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**ABSTRACT.** *Introduction:* Regular climbing can contribute to the maintenance and development of both mental and physical well-being. Studies investigate how regular indoor climbing affects the strength endurance of specific trunk and arm muscles, as well as the joint mobility of the trunk and hips in different planes. *Objective:* The aim of this study was to evaluate the influence of climbing on adolescents' static strength, muscular endurance, lower limb explosive strength, and flexibility within a 4-week program integrated into the school physical education curriculum. *Material and methods:* A total of 48 adolescents were randomly assigned to an intervention group (IG; n = 21; 8 boys, 13 girls; M = 15.33 ± 0.50 years) and a control group (CG; n = 27; 9 boys, 18 girls; M = 15.54 ± 0.50 years), with similar gender distributions across both groups. *Results:* After the four-week intervention, there was a significant change in the hand grip strength of the IG, namely, the strength of both the dominant (from M = 30.11, SD = 8.13 kg to M = 26.84, SD = 7.89 kg), and the non-dominant hand significantly decreased (from M = 26.84, SD = 7.98 kg to M = 24.00, SD = 7.91 kg). This phenomenon can also be observed in the CG. *Conclusion:* Considering the available facilities, the age group, and the allocated time for the intervention (4 weeks, 2 sessions per week, 50 minutes each), these conditions appear insufficient to elicit a significant positive change in the examined abilities.

**Keywords:** indoor climbing; physical education class; intervention study, adolescence.

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<sup>1</sup> Department of Individual Sports, Babeş-Bolyai University, Cluj-Napoca, Romania.

<sup>2</sup> Department of Physical Education, Reformed College of Cluj-Napoca, Romania

<sup>3</sup> Department of Physical Therapy and Theoretical Subjects, Babeş-Bolyai University, Cluj-Napoca, Romania, iuliana.borosbalint@ubbcluj.ro.

\* Corresponding author: bela.balla@ubbcluj.ro

## INTRODUCTION

Simpler forms of climbing can be mastered during the early years of human development. The movement structure of basic climbing forms remains essentially unchanged, from simple tree climbing to the ascent of a challenging rock face. In both cases, the same limbs are used, performing pulling and pushing movements either alternately or even simultaneously. According to Herbert (1912, p.58), "Climbing consists of raising or moving the body using the arms or both the arms and legs from a suspension or holding position. Climbing with the arms and legs recruits the muscles of the entire body, particular the core and upper limbs."

Regular climbing can contribute to the maintenance and development of both mental and physical well-being (Garber et al., 2011). Several studies have examined the effect of climbing on physical performance in healthy adults (Heitkamp, Wörner, & Horstmann, 2005; Muehlbauer, Stuerchler, & Granacher, 2012) and children (Balas & Bunc, 2007; Balas, Strejcova, Maly, Mala, & Martin, 2009). These studies investigate how regular indoor climbing affects the strength endurance of specific trunk and arm muscles, as well as the joint mobility of the trunk and hips in different planes. Additionally, many studies explore the therapeutic applications of indoor climbing.

The effect of climbing has been studied in conditions such as cerebral palsy (Böhm, Rammelmayer, & Döderlein, 2014), multiple sclerosis (Velikonja, Curić, Ozura, & Jazbec, 2010), cerebellar ataxia (Stephan et al., 2011), and back pain (Engbert & Weber, 2011; Kim & Seo, 2015). In addition to these studies, research has also been conducted in many other areas, a comprehensive overview of which can be found in the systematic review by Gassner et al. (2022).

## MATERIALS AND METHODS

### Participants

The participants were 9th-graders selected from a high school in Cluj-Napoca, Romania. A total of 48 adolescents were randomly assigned to an intervention group (IG;  $n = 21$ ; 8 boys, 13 girls;  $M = 15.33$ ,  $SD = 0.50$  years) and a control group (CG;  $n = 27$ ; 9 boys, 18 girls;  $M = 15.54$ ,  $SD = 0.50$  years), with similar gender distributions across both groups,  $\chi^2(1, N = 48) = 0.09$ ,  $p = .770$ . The results of the one-way multivariate analysis of variance (MANOVA) indicated no statistically significant differences at the multivariate level,  $F(7, 38) = 0.43$ ,  $p = .878$ , for any of the investigated independent variables.

Our study was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013) and approved by the ethics committee of the Faculty of Physical Education and Sports, Babeş-Bolyai University (V/1594-2/2022/EKU). All parents and students provided written informed consent prior to participation in the research.

The aim of this study was to evaluate the influence of climbing on adolescents' static strength, muscular endurance, lower limb explosive strength, and flexibility within a 4-week program integrated into the school physical education curriculum.

### **Procedure**

The intervention took place during physical education classes in the second module of the 2022/2023 school year and was announced as a regular physical education and sports program for the participants. The initial measurements were performed on November 18, 2022. The intervention itself was conducted from November 23, 2022, to December 16, 2022, over four weeks, twice a week, for a total of 8 sessions, each lasting 50 minutes (the duration of one lesson in Romanian schools) (Balla, Boros-Bálint, & Szatmári, 2022). The final physical tests were conducted on December 22, 2022.

For the experimental group, the intervention consisted of progressively more challenging climbing activities, while the control group participated in an additional hour of physical education, during which technical elements of basketball and volleyball were practiced.

For the participants practicing climbing activities, we initially introduced the basics of wall climbing, teaching them how to grip the holds. We then progressively engaged them in more challenging tasks, including different grip techniques, foot positions, body positioning on the wall, lateral climbing, traversing, and climbing vertically and then returning. At the end, we organized a competition that incorporated all these skills, specifying the directions and colors of the grips they were allowed to use.

All activities began with a thorough 8–10-minute warm-up, which included both dynamic and static exercises. The lessons were concluded with a 5-minute evaluation and feedback session. The classes were led by two physical education teachers, and in addition, graduate students (2 per class) were present to assist with the exercises.

### **Measures**

In this study, we applied six performance-based tests to measure different motor abilities, as well as two anthropometric tests.

### ***Performance-based tests***

1. **Handgrip Strength Test:** The Jamar hydraulic dynamometer was used to measure grip strength, which is considered the gold standard due to its high reliability and precision (Hamilton, McDonald, & Chenier, 1992). The test was performed with both hands according to the guidelines of the American Society of Hand Therapists (MacDermid, Solomon, & Valdes, 2015). The better result of the two attempts was recorded.

2. **Sit and Reach Flexibility Test:** This test was first described by Wells and Dillon in 1952 as a measure of back and leg flexibility. Mayorga-Vega, Merino-Marban, and Viciano (2014) in a meta-analysis of 34 studies found that 'sit-and-reach tests have moderate mean criterion-related validity for estimating hamstring extensibility, but they have low mean validity for estimating lumbar extensibility.' They also concluded that 'among all the sit-and-reach test protocols, the classic sit-and-reach test seems to be the best option to estimate hamstring extensibility.' The American College of Sports Medicine guidelines were followed when performing the test (ACSM, 2014).

3. **Standing Long Jump Test:** The broad jump is a common and simple test of explosive leg power. According to Rahman, Kamal, Noor, Geok, and Alnedral (2021), the standing long jump is a reliable and valid tool for measuring explosive leg power. Other studies also support the validity of the standing long jump test (Fernandez-Santos, Ruiz, Cohen, Gonzalez-Montesinos, & Castro-Piñero, 2015; Thomas et al., 2020).

4. **YMCA Sit-Up Test:** This test assesses the strength and endurance of the abdominal and hip-flexor muscles and was carried out with the subjects until exhaustion. The objective is to perform the maximum number of sit-ups. The subject performs the test with bent knees, feet flat on the floor about 45 cm from the buttocks, and hands touching the sides of the head. The examiner holds the subject's feet while the exercise is performed. The subject touches the opposite elbow to the alternate knee with each sit-up (Baumgartner & Jackson, 1999).

5. **Modified Knee Push-Up Test:** The purpose of this test is to assess upper-body endurance, and the objective is to perform push-ups to exhaustion. The examinees perform the arm flexion from a kneeling position, lowering the body toward the floor until the chin touches the mat (Baumgartner, Jackson, Mahar, & Rowe, 2016).

6. **Modified Pull-Up Test:** This test measures upper extremity strength and endurance of the elbow flexor muscles (Baumgartner, Jackson, Mahar, & Rowe, 2016). Its norm-referenced and criterion-referenced reliability was assessed by Saint Romain and Mahar in 2001. 'Norm-referenced and criterion-referenced test-

retest reliability estimates in this study were acceptable. However, criterion-referenced equivalence reliability findings were not acceptable' (Saint Romain & Mahar, 2001, p. 1).

### ***Anthropometric measurements***

#### **1. Measuring body weight**

An OMRON HBF-400 scale was used to measure the participants' body weight. Measurements were taken with minimal clothing and without shoes.

#### **2. Measuring body height**

A SECA 206 rolling measuring tape was used to measure the participants' height. Measurements were taken without shoes.

#### **3. Body Mass Index**

The BMI-for-age percentile was calculated based on the Centers for Disease Control and Prevention growth charts for children and adolescents ages 2 to 19 years.

### ***Physical activity level measurement***

The physical activity level of the sample was assessed using the PAQ-C questionnaire, which is a self-administered, 7-day recall instrument. 'It was developed to assess general levels of physical activity throughout the elementary school year for students in grades 4 to 8, approximately 8 to 14 years of age. The PAQ-C can be administered in a classroom setting and provides a summary physical activity score derived from nine items, each scored on a 5-point scale' (Kowalski, Crocker, & Donen, 2004, p. 6). The validated Hungarian version of the questionnaire was used (Makai et al., 2023).

One-way multivariate analysis of variance (one-way MANOVA), independent sample t-test, paired sample t-test, and Shapiro-Wilk test for normality were used. Statistical analysis was performed with a significance level of 0.05.

## **RESULTS**

The anthropometric characteristics of the sample are presented in Table 1. As shown, there were no significant differences between the two groups in terms of physical characteristics, for either boys or girls. 2.2% of the sample was underweight (0% boys, 3.3% girls), 66.7% had normal weight (68.8% boys, 83.3% girls), 6.5% were overweight (0% boys, 10.0% girls), and 13% were obese (31.3% boys, 3.3% girls).

The scores for physical activity level, sit and reach test, standing long jump, and body height were normally distributed for both the intervention group (IG) and control group (CG), as assessed by the Shapiro-Wilk test ( $p > .05$ ).

However, the scores for handgrip strength (dominant and non-dominant limbs), BMI, sit-ups, pull-ups, and push-ups were not normally distributed for either group ( $p < .05$ ). To obtain valid results from the use of parametric tests, we applied a transformation to the data.

**Table 1.** Comparison of the anthropometric results of the intervention and control groups

|                      | N  | Height [cm]                | Weight [kg]                | BMI                        | Age [year]                 |
|----------------------|----|----------------------------|----------------------------|----------------------------|----------------------------|
| IG Boys              | 8  | 175.25 ± 2.37              | 67.41 ± 17.46              | 21.86 ± 5.11               | 15.50 ± 0.53               |
| CG Boys              | 8  | 176.50 ± 7.36              | 79.01 ± 24.46              | 25.06 ± 6.04               | 15.38 ± 0.51               |
| Result of the t-test |    | t(14)= -.457,<br>p= 0.655  | t(14)= -1.092,<br>p= 0.293 | t(14)= -1.143,<br>p= 0.272 | t(14)= .475,<br>p= 0.642   |
| IG Girls             | 13 | 162.23 ± 5.87              | 54.17 ± 6.75               | 20.46 ± 2.43               | 15.23 ± 0.43               |
| CG Girls             | 16 | 164.83 ± 6.70              | 58.23 ± 9.77               | 21.36 ± 2.86               | 15.63 ± 0.50               |
| Result of the t-test |    | t(29)= -1.122,<br>p= 0.271 | t(28)= -1.252,<br>p= 0.221 | t(28)= -.888,<br>p= 0.382  | t(27)= -2.229,<br>p= 0.340 |

Note: IG – intervention group; CG – control group.

The initial pre-intervention strength, flexibility, and endurance tests did not show significant differences between the groups (significance level from  $p = .051$  to  $p = .885$ ).

A paired-samples *t*-test was used to determine whether there was a statistically significant mean difference between dominant and non-dominant hand grip strength. No outliers were detected that were more than 1.5 box-lengths from the edge of the box in the boxplot. Inspection of the values did not reveal any extreme cases, and they were retained in the analysis. The assumption of normality was not violated, as assessed by the Shapiro-Wilk test ( $p = .121$  and  $p = .131$ ). Participants exerted greater hand grip strength with their dominant hand ( $M = 39.31$ ,  $SD = 1.44$  kg) than with their non-dominant hand ( $M = 36.87$ ,  $SD = 1.15$  kg). A statistically significant mean difference of 2.44 kg, 95% CI [36.23, 42.39],  $t(46) = 5.24$ ,  $p < .001$ ,  $d = 3.36$ , was observed.

The following tests were used to measure the strength and endurance of different muscles: sit-ups, modified push-ups, and modified pull-ups. A Pearson's product-moment correlation was run to assess the relationship between sit-up performance, push-up performance, and pull-up performance in males of the IG and CG groups ( $n = 16$ ). Preliminary analyses showed the relationship to be linear, with one variable normally distributed and two variables not normally distributed, as assessed by the Shapiro-Wilk test ( $p = .009$ ,  $p = .628$ ,  $p = .001$ ). There was a single outlier, which was retained in the analysis. A statistically significant, moderate positive correlation was found between the strength and

endurance of the abdominal and hip-flexor muscles and the strength and endurance of the flexor muscles of the elbow,  $r(15) = .49, p = .045$ . Also, a moderate positive statistically significant correlation was found between the strength and endurance of the abdominal muscles and upper-body endurance,  $r(15) = .50, p = .050$ . The BMI showed a negative statistically significant correlation with the strength and endurance of the muscles. The results are as follows: BMI – Sit-ups,  $r(15) = -.58, p = .020$ ; BMI – Pull-ups,  $r(15) = -.65, p = .001$ ; BMI – Push-ups,  $r(15) = -.49, p = .050$ . In the case of girls, this correlation could not be found between the three mentioned variables ( $p = .312, p = .679$ ). No significant differences were found between the mean values for the seven variables presented in Table No. 2 and Table No. 3.

**Table 2.** The pre-test results of the boys on the performance tests

|                | N  | DHGS     | NDHGS    | Sit-ups   | Pull-ups | Push-ups  | SAR      | SLJ        |
|----------------|----|----------|----------|-----------|----------|-----------|----------|------------|
| IG Boys        | 8  | 39.0±4.8 | 35.6±4.3 | 59.2±28.6 | 10.0±5.5 | 37.0±25.1 | 4.7±3.6  | 188.6±23.4 |
| CG Boys        | 8  | 39.6±6.9 | 38.1±4.8 | 37.6±12.9 | 5.8±5.1  | 16.6±9.7  | -0.4±9.5 | 182.1±38.6 |
| $\bar{x}$ Boys | 16 | 39.3±5.7 | 36.8±4.6 | 48.4±24.2 | 7.9±5.5  | 26.8±21.2 | 2.1±7.4  | 185.3±31.1 |

*Note:* DHGS = dominant hand grip strength; NDHGS = non-dominant hand grip strength; SAR = sit and reach; SLJ = standing long jump.

**Table 3.** The pre-test results of the girls on the performance tests

|                 | N  | DHGS     | NDHGS    | Sit-ups   | Pull-ups | Push-ups | SAR      | SLJ        |
|-----------------|----|----------|----------|-----------|----------|----------|----------|------------|
| IG Girls        | 13 | 24.6±2.4 | 21.7±3.8 | 37.6±19.0 | 1.8±2.5  | 11.7±8.3 | 10.0±7.8 | 158.1±15.2 |
| CG Girls        | 18 | 26.0±4.7 | 24.0±5.1 | 42.0±28.0 | 2.8±4.5  | 12.7±8.1 | 12.3±6.9 | 162.4±23.3 |
| $\bar{x}$ Girls | 31 | 25.5±3.9 | 23.1±4.7 | 40.2±24.4 | 2.4±3.8  | 12.3±8.1 | 11.4±7.3 | 160.6±20.2 |

*Note:* DHGS = dominant hand grip strength; NDHGS = non-dominant hand grip strength; SAR = sit and reach; SLJ = standing long jump

We measured the level of physical activity using the PAQ-C. The physical activity level was  $M = 2.40, SD = 0.57$  in the intervention group (IG) and  $M = 2.37, SD = 0.53$  in the control group (CG). There was no statistically significant difference between the two groups,  $t(46) = 0.21, p = .837$ .

### ***Results of the 4-week intervention program***

After the four-week intervention, there was a significant change in the hand grip strength of the IG, namely, the strength of both the dominant ( $M = 30.11, SD = 8.13$  kg to  $M = 26.84, SD = 7.89$  kg), and the non-dominant hand

significantly decreased ( $M = 26.84$ ,  $SD = 7.98$  kg to  $M = 24.00$ ,  $SD = 7.91$  kg), as shown by the paired-samples  $t$ -test, 95% CI [2.21, 4.31],  $t(18) = 6.52$ ,  $p < .001$ ,  $d = 3.36$ . This phenomenon can also be observed in the CG, the strength of the dominant hand decreased from  $M = 30.08$ ,  $SD = 8.22$  kg to  $M = 27.86$ ,  $SD = 9.60$  kg, the strength of the non-dominant hand decreased from  $M = 28.17$ ,  $SD = 8.23$  kg to  $M = 25.52$ ,  $SD = 8.53$  kg, 95% CI [0.86, 3.56],  $t(22) = 3.41$ ,  $p < .05$ ,  $d = 0.71$ .

Of the six tests used, only the modified pull-up test showed a significant improvement in performance ( $M = 4.68$ ,  $SD = 5.22$  to  $M = 5.94$ ,  $SD = 6.81$ ), 95% CI [-2.40, -0.11],  $t(18) = -2.32$ ,  $p < .05$ ,  $d = 0.53$ . This improvement was observed in both the experimental and control groups. The results of the performance tests are presented in Table 4.

**Table 4.** The post-test results of the intervention and control group on the performance tests

|                 | <b>Intervention Group</b> | <b>Control group</b> | <b>Results of the t-test</b>   |
|-----------------|---------------------------|----------------------|--------------------------------|
| <b>DHGS</b>     | 26.84±7.89                | 28.50±9.89           | $t(41) = -0.595$ , $p = 0.555$ |
| <b>NDHGS</b>    | 24.00±7.91                | 26.20±9.00           | $t(41) = -0.842$ , $p = 0.405$ |
| <b>Pull-ups</b> | 5.94±6.81                 | 5.29±6.01            | $t(41) = 0.335$ , $p = 0.739$  |
| <b>Push-ups</b> | 21.10±13.41               | 15.70±9.05           | $t(41) = 1.572$ , $p = 0.124$  |
| <b>Sit-ups</b>  | 48.31±24.69               | 45.66±25.24          | $t(41) = -0.766$ , $p = 0.448$ |
| <b>SAR</b>      | 8.52±7.86                 | 7.83±6.34            | $t(41) = 0.320$ , $p = 0.751$  |
| <b>SLJ</b>      | 170.52±27.85              | 165.54±29.30         | $t(41) = 0.566$ , $p = 0.575$  |

*Note:* DHGS = dominant hand grip strength; NDHGS = non-dominant hand grip strength; SAR = sit and reach; SLJ = standing long jump

The independent-samples  $t$ -test showed no significant difference between the performance of the two groups for any measured variable. The physical activity level of the groups did not differ significantly in the seven days before the intervention (IG:  $M = 2.32$ ,  $SD = 0.48$ ; CG:  $M = 2.43$ ,  $SD = 0.54$ ), and likewise at the end of the intervention, we did not measure any significant difference between the groups (IG:  $M = 2.42$ ,  $SD = 0.49$ ; CG:  $M = 2.33$ ,  $SD = 0.37$ ), 95% CI [-0.18, 0.36],  $t(39) = 0.66$ ,  $p = .515$ .

## DISCUSSION

The aim of the present study was to investigate how indoor wall climbing affects the physical abilities of 9th-grade students, specifically grip strength, lower extremity explosiveness, abdominal and hip flexor muscle strength and endurance, upper body endurance, and back and leg flexibility. The study was conducted



within a solid theoretical framework as a field experiment, incorporating a control group. To the best of our knowledge, this is the first study of its kind to address this topic within the context of school physical education in Romania.

Balas and Bunc (2007) conducted a ten-week climbing-based intervention with 7- to 9-year-old children. The intervention consisted of 45-minute sessions, held twice a week. According to their results, this duration was insufficient for the development of static strength and muscle endurance in this age group when implemented within the context of school physical education.

In a 2017 study, children aged 11–13 spent 2.5 hours, three times a week for three weeks, in a climbing hall with a 600 m<sup>2</sup> wall. The sample was divided into two groups: one with children with cerebral palsy and the other with typically developing children. Among other tests, hand grip strength was measured; however, a significant increase in strength was observed only in the group with cerebral palsy (Christensen, Jensen, Voigt, Nielsen, & Lorentzen, 2017).

In a 2009 study, Balas, Strejcova, Maly, Mala, and Martin conducted an intervention with children aged 10–17 years, in which they examined, among other factors, hand grip strength and arm strength endurance in a bent suspension. Although the subjects participated in as many sessions as possible over the eight weeks, the frequency of participation did not significantly affect their performance. Instead, the climbing distances covered during the sessions led to improved performance in both sexes. As stated by Balas et al. (2009), ‘there was a significant increase in relative grip strength for both hands in boys and girls with higher climbing volume’ (p. 177).

Considering the available facilities, the age group, and the time allocated for the intervention (4 weeks, 2 sessions per week, 50 minutes each), it is not surprising that the measured abilities—such as back and leg flexibility, explosive leg power, and strength and endurance—did not show significant changes. In the aforementioned studies, the interventions lasted longer, yet they still failed to produce measurable changes at the end of the intervention. The most notable result in our study was the significant decrease in grip strength in both the dominant and non-dominant hands for both the experimental and control groups. We are unaware of any specific factors during the intervention that could have contributed to this decrease in grip strength performance.

Similar interventions conducted with adult participants typically confirm that at least 8 weeks of appropriate training, twice a week, is required to observe measurable effects (Heitkamp, Wörner, & Horstmann, 2005). This is consistent with the findings of Muehlbauer, Stuerchler, & Granacher (2012), where nearly all measured variables showed significant improvements, including positive changes in core strength, hand-grip strength, and trunk mobility.

### **Limitations of the study**

The participants joined the intervention voluntarily; however, some appeared to lack sufficient motivation when performing the climbing tasks. Although we had access to two 4x4 meter vertical climbing walls (32 square meters in total), which allowed 4-6 trainees to engage in physical activity simultaneously, the class size of 20 students may have affected the effectiveness of the intervention. The density of physical education classes may not have been optimal for providing each participant with adequate attention and time for performing the tasks.

The modular structure of the academic year implemented in Romania starting in 2022 posed challenges for extended interventions. The presence of 1–2-week breaks between modules would have disrupted the continuity of the intervention. As a result, we were constrained to plan and execute the intervention within the timeframe of a single module.

### **Author contributions**

Conceptualization, B.B.J. and B.-B.I.; methodology, B.B.J.; formal analysis, B.B.J.; investigation, B.B.J. and F.I.; writing—original draft preparation, B.B.J.; writing—review and editing, B.B.J.; visualization, B.B.J.; supervision, B.B.J. and B.-B.I.; project administration, B.B.J. and B.-B.I.

### **Conflicts of Interest**

The authors declare no conflict of interest.

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