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STANDARDIZATION OF EFFORT PARAMETERS IN ACCORDANCE WITH THE PHYSIOLOGICAL CHARACTERISTICS OF WOMEN APPLIED IN HANDBALL. A SYSTEMATIC REVIEW

Octavian POPESCU[1*], Simona PETRACOVSCHI[1]

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.

[1] West University of Timişoara, Romania
[*] Corresponding author: octavian.popescu@e-uvt.ro

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.

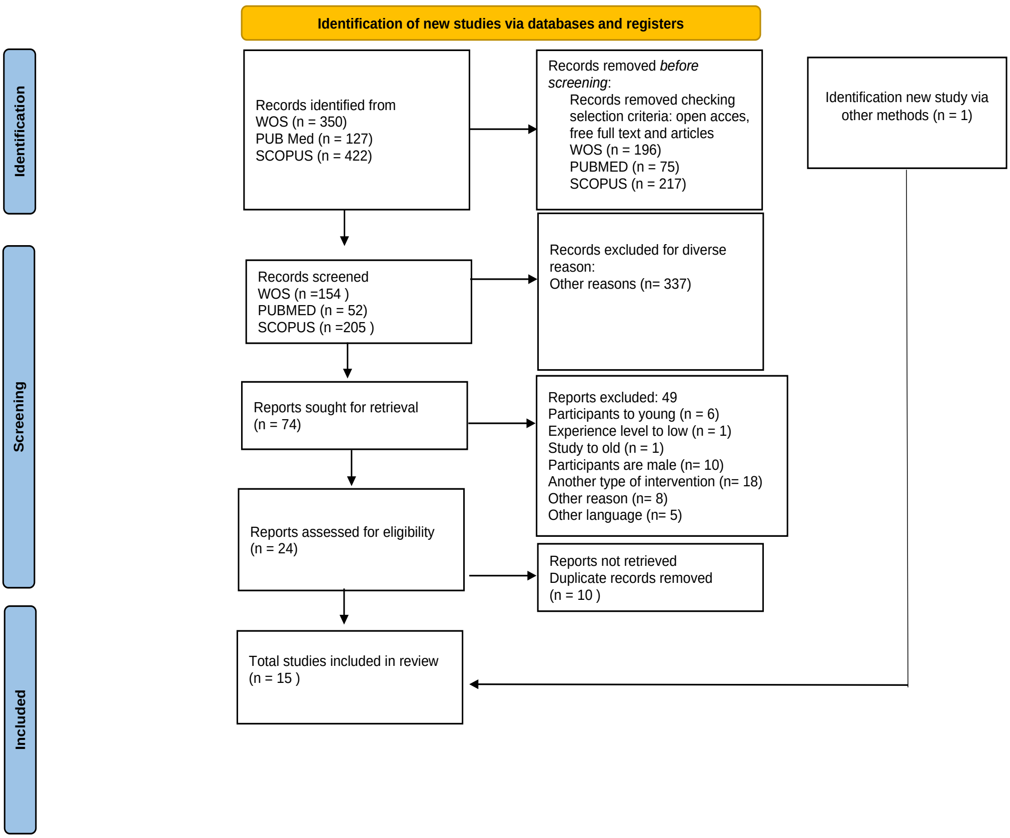

Fig. 1. Prisma Diagram

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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