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Comparative analysis of two strength training protocols on throwing speed in women's handball
Análisis comparativo de dos protocolos de entrenamiento de fuerza sobre la velocidad de lanzamiento en balonmano femenino

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Abstract. Shooting represents a fundamental skill in handball. Among other factors, its effectiveness requires a significant development of explosive strength. Isometric training may provide a powerful neuromuscular stimulus for its enhancement. Despite its importance and practicality, few studies have addressed the effect of this type of training on shooting speed in women's handball. Twenty female players were divided into two groups: isometric training (IG, n=10) and dynamic training (DG, n=10). Over nine weeks, twice a week, both groups completed an upper limb pushing resistance training: IG performed maximum isometric strength, and DG performed dynamic strength at 80% of one maximum repetition (1MR). In both cases, the effort was followed by medicine ball throws. The loads for both groups were equated in terms of sets and duration. Pre- and post-intervention, the 1MR of each player was estimated through a load progression test in bench press exercise. Additionally, the shooting speed with and without aiming at a target was measured from seven and nine meters using a radar. The findings showed a trend towards improvement in both groups (slightly higher in IG); however, only the not-targeted *shooting speed from 9 meters* in IG reached statistical significance ($p < .05$). The correlation between 1MR and shooting speed was low to moderate. In summary, both types of training yielded similar results. Given the practical advantages of isometric training, it could be suggested that this training could serve as an effective and practical alternative for enhancing strength and shooting speed in handball.
Keywords: Handball, handball shooting, isometric strength training, women's sport.

Resumen. El lanzamiento a portería constituye una habilidad fundamental en balonmano. Su efectividad requiere, entre otros factores, un desarrollo significativo de la fuerza explosiva. El entrenamiento isométrico puede proporcionar un potente estímulo neuromuscular para su incremento. A pesar de su importancia y practicidad, pocos estudios han abordado el efecto de este tipo de entrenamiento sobre la velocidad del lanzamiento en balonmano femenino. En el presente trabajo, 20 jugadoras fueron divididas en dos grupos: entrenamiento isométrico (GI, n=10) y entrenamiento dinámico (GD, n=10). Durante nueve semanas, dos veces a la semana, ambos grupos entrenaron fuerza de empuje de miembros superiores: GI realizó fuerza isométrica máxima y GD fuerza dinámica al 80% de una máxima repetición (1RM). En ambos casos el esfuerzo fue seguido por lanzamientos de balones medicinales. Las cargas de ambos grupos fueron equiparadas en términos de series y duración. Pre y post intervención se estimó el 1RM de cada jugadora mediante una prueba de progresión de cargas en el ejercicio de *press* de banca. También se midió, mediante un radar, la velocidad de lanzamiento con y sin puntería a un blanco desde una distancia de siete y de nueve metros. Los resultados mostraron tendencia a la mejora en ambos grupos (ligeramente mayor en GI); pero únicamente la *velocidad de lanzamiento sin puntería* desde los 9 metros en GI alcanzó significancia estadística ($p < 0,05$). La correlación entre el 1RM estimado y la velocidad de lanzamiento fue baja a moderada. En suma, ambos tipos de entrenamiento mostraron resultados similares. Dada las ventajas prácticas que ofrece el entrenamiento isométrico, los hallazgos sugieren que dicho entrenamiento podría constituirse en una alternativa eficaz y práctica para la mejora de la fuerza y velocidad de lanzamiento en balonmano.
Palabras claves: Balonmano, lanzamiento en balonmano; entrenamiento isométrico de fuerza, deporte femenino.

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Introduction

Handball is a sport that requires, among other skills, the ability to accelerate, jump, and shoot with high efficacy. The latter represents a fundamental skill that players in this sport must train and perfect to increase their chances of success (Laguna, 2019).

Speed and accuracy are the primary factors defining shooting effectiveness (Ortega-Becerra, et al., 2018). Speed is crucial so that opponents, whether the goalkeeper or a field player, have less reaction time to stop or block the ball, and accuracy is essential to deceive and place the ball where the player wants to (Van den Tillaar, 2020). It has been reported that faster shots are more likely to result in goals (Zapardiel, et al., 2017). To achieve this, optimal force production during the shot execution must occur in the shortest possible time. At the elite level, it has been observed that in the women's category, shots from different positions on the field and towards different areas of the goal tend to result in fewer scores compared to their male counterparts (Gómez-López, et al., 2021). The disparity in goal-scoring rates between sexes could be partially explained by the higher average levels of strength observed among men. Greater strength is associated with an enhanced potential for force generation during shooting, highlighting the important role of strength training in achieving optimal performance (Wagner et al., 2019). According to Dietz and Peterson (2012), the technical gesture of shooting involves a dynamic movement with a triphasic nature, allowing its analysis based on the study of its three phases: eccentric, isometric, and concentric. The eccentric phase, or arm cocking, enables the accumulation of kinetic energy in the tendons and other elastic components of the myofascial system involved. The isometric phase transfers the energy absorbed during the eccentric phase into explosive concentric actions. The concentric phase represents the actual throwing motion. These authors suggest that to generate the maximum amount of force in the shortest possible time during the shot, training the three mentioned phases with varied exercises is necessary, thereby inducing continuous adaptations in the athletes.

Previous studies have observed that shooting speed can be increased through various training methods, including power-oriented training, central stability training, and medicine ball throws (Løken, et al., 2021). Additionally, there is evidence that isometric training, particularly those performed at various joint angles, significantly improves strength and power for dynamic movements. Nevertheless, despite its ease and practicality, this type of training is underutilized (Fleck & Kraemer, 2017).

In the present study, we aimed to compare the effect of a training protocol that applies isometric tension vs. a dynamic strength training protocol (more commonly used in this sport) in a sample of experienced female handball players. To achieve this, we analyzed and compared the impact of upper limb pushing resistance training in isometric vs. dynamic form on shooting speed. In both cases, the athletes performed medicine ball throws after the resistance exercises. Although some studies suggest that throwing speed does not affect accuracy and vice versa (Van den Tillaar, 2020), due to the lack of consensus on this topic (Cherif, et al., 2016; Van den Tillaar, 2020; Van den Tillaar & Ettema, 2003; Vila, et al., 2020), in addition to its relevance for athletic performance, we decided to include the latter variable in the present study.

To our knowledge, few studies have addressed this topic, especially with women. In this regard, the findings could provide valuable insights for coaches of high-level female teams when designing resistance training programs focused on shooting.

Materials and methods

Research design

This study employed a quasi-experimental design with pre- and post-intervention assessments. The research was approved by the Ethics Committee of the Instituto Universitario Asociación Cristiana de Jóvenes (IUACJ) of Uruguay and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (Rev. 2008).

Participants

Twenty female players from a handball team competing in the Uruguayan Handball Federation Championship were selected to participate in the study. This competition is considered the highest level for this sport in Uruguay. At the time of the intervention, the team had won the last four national championships (2018 to 2021). Nine of the selected players belonged, or had belonged, to the National Senior Team of this sport, and four among them had also experienced training and competing in high-level international clubs.

The inclusion criteria were the following: i) to have medical clearance to participate in sports activities and competitions; ii) not to have injuries that could affect physical performance; iii) not to be taking medications that could affect performance; and iv) to have read and signed the corresponding informed consent. As exclusion criteria, it was considered i) not achieving 70% of the planned training sessions in the experimental intervention and ii) the absence from two consecutive training sessions.

Procedures

The 20 players were divided into two experimental groups: the isometric group (IG, n = 10) and the dynamic group (DG, n = 10). The division was performed using the matching technique. According to this technique, the sample is segmented by matching the groups about some specific variable, which can decisively influence the dependent variable (Hernández-Sampieri, et al., 2014). In the present work, the division was made considering each participant's 1MR bench press value (estimated through the protocol described in the assessment section).

The IG and DG players continued with their usual training throughout the duration of the experimental intervention. None of the participants undertook additional upper limb strength training outside the scheduled training sessions.

Assessments

The week before the initial assessment, all players underwent sessions resembling the tests and training sessions planned for the study. The purpose was to identify and rectify potential technical errors and familiarize players with the various tests and exercises, minimizing the learning bias. The assessments outlined below were carried out the following week and repeated the week after completing the experimental intervention under identical conditions.

On Tuesday, the bench press test was carried out following a standardized 10-minute warm-up, which included shoulder mobility, muscle activation exercises, and two sets of the movement to be assessed without added load. The test involves sets of 4 repetitions each, with progressively heavier weights. It begins with the Olympic-type barbell (15kg mass) and subsequent increments of 10kg until reaching a load of 45kg. A recovery time of three to four minutes was established between each set. During the test, participants were instructed to emphasize the positive phase, moving the bar as fast as possible until achieving fully extended elbows. Control was maintained over the negative phase of the movement to prevent bouncing against the athlete's chest. A linear encoder (Vitruve Encoder, Speedlifts S.L., Spain) was used to record the trajectory and speed of movement. The data were analyzed using the corresponding equipment software, calculating the average speed of the four repetitions performed during each instance. From this, the estimated 1MR value was derived (figure 1). On Thursday of the same week, after a general and specific handball warm-up of approximately 15min (comprising shoulder mobility, muscle activation exercises and varied passes between players), throwing assessments were conducted using the official ball of the season (Blesbok, Meraki n °2). Each player was instructed to execute two types of shooting with their dominant upper limb (meaning the limb usually used for shooting at the goal): i) standing shots from a distance of seven meters from the goal, with the foot opposite to the throwing arm positioned in front of the ipsilateral foot, and without jumping (figure 2); and ii) jumping shots from a distance of nine meters from the goal, preceded by three steps before jumping and releasing the ball. These distances were chosen for the following reasons: the first corresponds to the penalty shot distance, while the second aligns with the range from which shots on goal are most frequently taken (Hatzimanouil, 2019). All shots were required to be executed with the highest possible speed. Each player performed 20 shots, 10 from the seven-meter zone and 10 from the nine-meter zone. Within each distance, five of the 10 shots were aimed at a target. For this purpose, a 63 cm diameter hoop was positioned in the goal, fixed at the same distance from the vertical posts, with its upper segment in contact with the crossbar. It is worth noting that although the instruction given to the players was to try to introduce the ball into the hoop, later, for calculating the shooting speed with aiming, all shots were considered, regardless of whether they successfully targeted the hoop or not. The players had a recovery time between each shot of at least two minutes. All shots were supervised simultaneously by two experienced handball coaches.

Figure 1. Flat bench, barbell and linear Encoder used to perform the maximum voluntary repetition (1MR) test in the bench press exercise

The ball speed was measured with a speed radar (Stalker Sport 2, 24.125 GHz, United States) placed 2m behind the player. It was adjusted individually, according to the height of the player's throwing arm, in agreement with the protocol described by Van den Tillaar (2020). Whether or not the ball entered the hoop was assessed by a video camera (16 MP, 8 MP wide-angle with a 120-degree field of view and 2 MP sensor) placed 15m from the goal. The average shooting speed for each distance (7m and 9m), type of shot (with and without aiming), and moment (pre- and post-intervention), measured in km/h, was used for subsequent analysis.

Figure 2. Shooting seven meters from the goal, with the foot contralateral to the throwing arm in front of the ipsilateral foot, without moving the forward foot and without jumping. In the upper part of the goal, the hoop used for the aiming shots can be seen.

Experimental intervention

The intervention lasted nine weeks and was conducted during the competitive season. During this time, and under similar conditions for all players, technical-tactical training (Monday, Wednesday and Friday) and physical conditioning exercises (Tuesday and Thursday) were carried out. All sessions had an approximate duration of 2 hours and 15 minutes. Additionally, the players took part in competitions during the weekends.

On Tuesdays and Thursdays, at the start of each session and after a standardized warm-up, the players performed the resistance training protocol corresponding to their experimental group: bench press or isometric pushing, followed by three maximum-speed throws of 1kg medicine balls with each arm. In the first week, both groups performed three sets of this sequence of exercises per session and four sets in the remaining weeks. The IG group performed maximal isometric tension against an immovable resistance for 6s, in two different positions. The bar was placed immediately below the bench stops, located at a height of 18cm and 13cm, measured from the support surface of the athlete's back to the lower edge of these stops (figure 3). This position resulted in elbow flexion angles of 103.0 ± 5.5 and 86.4 ± 2.3 degrees, respectively (figure 4). The grip width of the bar was adjusted for each player, ensuring that when the elbows were at the trunk level, they reached 90 degrees of flexion. The first set of each session always started with the bar positioned below the lower stop; thereafter, the bar position alternated between the two positions for the remaining sets.

Figure 3. Distance measured from the bench back support surface to the bottom edge of the lower and upper stops.

Figure 4. Average angle of elbow flexion, at the moment when the athletes of the Isometric Group (IG) performed the effort with the bar located below the upper and lower stop (left and right image, respectively)

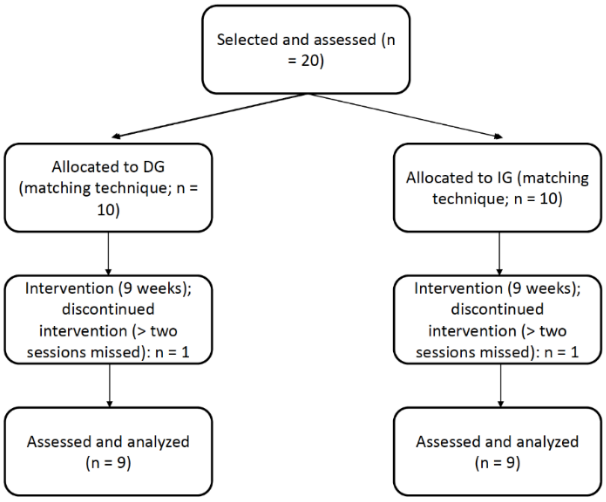

Figure 5. Diagram of the procedures carried out in the current study.

The players were instructed to exert maximum tension throughout the effort, receiving continuous verbal encouragement. Following the isometric tension exercise, the players immediately transitioned to the next phase without any rest period. They were required to grab a medicine ball and execute three horizontal throws with the right upper limb and three with the left upper limb, aiming for maximum speed in each throw. A passive rest period of five minutes was implemented between each series.

In the DG group, each player was instructed to complete as many bench press repetitions as possible with 80% of their 1MR for a duration of 6 seconds. Following this, the players executed medicine ball throws under the same conditions as their counterparts in the IG group. In week five, the DG group underwent a reassessment, according to the protocol previously described, to readjust the training loads in the bench press if there were any changes in their 1MR values.

A diagram of the procedures carried out in the current study is shown in figure 5.

Data analysis

The data are presented as mean ± SD. Normality was assessed by the Kolmogorov-Smirnov test, and homogeneity of variances by the Levene test. If these assumptions were met, the potential differences between DG and IG were analyzed using Student's t-test for independent data before and after the experimental intervention. The Mann-Whitney U test was employed if the normality or homogeneity of variances was not met. To compare within each group pre- vs. post-intervention, a repeated measures ANOVA test with Bonferroni correction was applied.

Finally, Pearson's correlation coefficient was employed to examine the relationship between estimated maximum strength and shooting speed after verifying that these variables fulfilled the assumptions of normality, linearity, and absence of outliers. The correlation strength was interpreted following the criteria proposed by Hopkins et al. (2009), which categorizes associations as poor if values are smaller than 0.1, low for values greater or equal to 0.1 and smaller than 0.3, moderate for values greater or equal to 0.3 and smaller than 0.5, high for values greater or equal to 0.5 and smaller than 0.7, very high for values greater or equal to 0.7 and smaller than 0.9, and almost perfect for values equal to or greater than 0.9.

In all cases, a significance level of $p < .05$ was considered. The statistical analysis was performed with the free software JASP (Version 0.16.4; JASP Team, 2022).

Results

Two of the initially selected 20 players (one from the IG group and one from the DG group) did not meet the established criteria, as they missed two consecutive training sessions. As a result, the analysis was conducted using data from the remaining 18 players (mean age = 25.0 ± 5.8 years; mean body mass index = 24.3 ± 2.0 kg/m^2; average training experience = 12.0 ± 6.4 years).

Table 1 illustrates the performance comparison between both groups before and after the resistance training program intervention. No significant differences ($p \geq .05$) were observed between the groups in pre- and post-intervention assessments, indicating similar performance in the analyzed variables. In both the IG and DG groups, at both distances (7m and 9m), and in both instances (pre- and post-intervention), the average number of successful shots into the hoop ranged between 2 and 3 out of a total of 5. We emphasize that when calculating shooting speed with accuracy, we did not consider whether the ball went through the hoop.

Table 1.
Comparison of shooting speed and maximal strength between IG (n = 9) and DG (n = 9) pre- and post-intervention

	IG pre Mean ± SD	DG pre Mean ± SD	IG vs. DG pre p value	IG post Mean ± SD	DG post Mean ± SD	IG vs. DG post p value
Sp. w/o aim 7m (km/h)	64.2 ± 6.6	64.7 ± 4.3	1.000	67.0 ± 4.0	64.8 ± 4.1	1.000
Sp. w/o aim 9m (km/h)	68.3 ± 6.7	68.7 ± 3.2	1.000	70.2 ± 6.5	69.3 ± 5.0	1.000
Sp w/ aim 7m (km/h)	59.2 ± 6.0	55.4 ± 3.7	1.000	61.2 ± 7.9	58.7 ± 4.7	1.000
Sp w/ aim 9m (km/h)	66.0 ± 7.0	66.2 ± 4.0	1.000	68.0 ± 7.4	66.2 ± 6.2	1.000
1MR (kg)	45.4 ± 8.0	44.3 ± 6.4	1.000	48.0 ± 7.3	46.7 ± 7.3	1.000

Abbreviations: Sp. = speed; w/o aiming = without aiming; w/ aim = with aiming; 1MR = maximum force for one repetition in bench press exercise; DG = dynamic group; IG = isometric group; SD = standard deviation). Asterisk (*) indicates statistical significance ($p < .05$).

Table 2 compares the intragroup performance within each group by contrasting the results obtained after the intervention with those recorded before it. In the DG group, there were no significant differences in performance ($p \geq .05$) post- vs. pre-intervention for any of the variables. However, in the IG group, statistically significant differences ($p < .05$) were observed only for speed without aiming from 7m, favoring post-intervention performance.

Table 2.
Comparison of shooting speed and maximal strength of both groups pre- vs. post-intervention (IG, n = 9; DG, n = 9)

	IG pre Mean ± SD	IG post Mean ± SD	IG pre vs. post p value	DG pre Mean ± SD	DG post Mean ± SD	DG pre vs. post p value
Sp. w/o aim 7m (km/h)	64.2 ± 6.6	67.0 ± 4.0	.037*	64.7 ± 4.3	64.8 ± 4.1	1.000
Sp. w/o aim 9m (km/h)	68.3 ± 6.7	70.2 ± 6.5	1.000	68.7 ± 3.2	69.3 ± 5.0	1.000
Sp. w/ aim 7m (km/h)	59.2 ± 6.0	61.2 ± 7.9	1.000	55.4 ± 3.7	58.7 ± 4.7	.352
Sp. w/ aim 9m (km/h)	66.0 ± 7.0	68.0 ± 7.4	1.000	66.2 ± 4.0	66.2 ± 6.2	1.000
1 MR (kg)	45.4 ± 8.0	48.0 ± 7.3	.141	44.3 ± 6.4	46.7 ± 7.3	.218

Abbreviations: Sp. = speed; w/o aim = without aiming; w/ aim = with aiming; 1MR = maximum force for one repetition in bench press exercise; DG = dynamic group; IG = isometric group; SD = standard deviation. Asterisk (*) indicates statistical significance ($p < .05$).

Table 3 compares shooting velocities without vs. with aiming from 7m and 9m, respectively, both pre- and post-intervention. This comparison is presented separately for each group (IG and DG) and for the total number of subjects (IG + DG). Except for the shooting speed from 7m pre-intervention in IG and the shooting speed from 9m post-intervention in IG and DG, all other shooting velocities without vs. with aiming exhibited significant differences, consistently favoring velocities without aiming.

Table 3.
Comparison of shooting speed without vs. with aiming (IG, n = 9; DG, n = 9)

	Group	W/o aiming Mean ± SD	W/ aiming Mean ± SD	W/o vs. W/ aiming p value
Sp. 7m pre (km/h)	IG	64.2 ± 6.6	59.2 ± 6.0	.018*
Sp. 9m pre (km/h)	IG	68.3 ± 6.7	66.0 ± 7.0	.256
Sp. 7m post (km/h)	IG	67.0 ± 4.0	61.2 ± 7.9	.015*
Sp. 9m post (km/h)	IG	70.2 ± 6.5	68.0 ± 7.4	.125
Sp. 7m pre (km/h)	DG	64.7 ± 4.3	55.4 ± 3.7	< .001*
Sp. 9m pre (km/h)	DG	68.7 ± 3.2	66.2 ± 4.0	.050*
Sp. 7m post (km/h)	DG	64.8 ± 4.1	58.7 ± 4.7	.001*
Sp. 9m post (km/h)	DG	69.3 ± 5.0	66.2 ± 6.2	.067
Sp. 7m pre (km/h)	IG+DG	64.4 ± 5.4	57.3 ± 5.2	< .001*
Sp. 9m pre (km/h)	IG+DG	68.5 ± 5.1	66.1 ± 5.5	.036*
Sp. 7m post (km/h)	IG+DG	65.9 ± 4.1	60.0 ± 6.4	< .001*
Sp. 9m post (km/h)	IG+DG	69.8 ± 5.7	67.1 ± 6.7	.013*

Abbreviations: Sp. = speed; w/o aim = without aiming; w/ aim = with aiming; DG = dynamic group; IG = isometric group; SD = standard deviation). Asterisk (*) indicates statistical significance ($p < .05$).

Table 4 illustrates the correlation between strength and shooting speed for each group, pre- and post-intervention.

In the IG group, a high positive correlation was observed pre-intervention between maximal strength (1MR) in the bench press and shooting speed without aiming from 7m and 9m, as well as between 1MR and shooting speed with aiming from 7m post-intervention. The correlation was low for shooting speed without aiming from 9m post-intervention. For the rest of the variables analyzed, the correlation was moderate. However, in all these cases, the correlation did not reach statistical significance ($p \geq .05$).

For the DG group, a very high and statistically significant positive correlation was observed between 1MR and shooting velocities of i) 7m with aiming pre-intervention and ii) 7m with aiming post-intervention. The correlation between 1MR and shooting speed with aiming from 9m post-intervention also reached statistical significance, which was classified as high. Shooting velocities without and with aiming from 9m pre-intervention showed a low, non-significant correlation with 1MR. The remaining correlations between 1MR and shooting speed were moderate and did not reach statistical significance.

Table 4.
Correlation between maximal strength and shooting speed in each group pre- and post-intervention

	IG (n = 9)		DG (n = 9)	
	Pearson r	p value	Pearson r	p value
Sp. w/o aim 7m vs. 1MR pre	.543	.131	.526	.146
Sp. w/o aim 9m vs. 1MR pre	.612	.080	-.183	.638
Sp. w/ aim 7m vs. 1MR pre	.372	.324	.747*	.021*
Sp. w/ aim 9m vs. 1MR pre	.331	.385	.181	.641
Sp. w/o aim 7m vs. 1MR post	.352	.353	.789*	.011*
Sp w/o aim 9m vs. 1MR post	.263	.495	.559	.117
Sp. w/ aim 7m vs. 1MR post	.588	.096	.599	.088
Sp. w/ aim 9m vs. 1MR post	.368	.329	.699*	.036*

Abbreviations: Sp. = speed; w/o aim = without aiming; w/ aim = with aiming; 1MR = maximum force for one repetition in bench press exercise; DG = dynamic group; IG = isometric group. Asterisk (*) indicates statistical significance ($p < .05$).

Discussion

The present study aimed to compare and analyze the impact of two types of upper limb pushing strength training protocols, one based on isometric contraction and the other on dynamic contraction (with concentric emphasis), followed by medicine ball throws, on shooting speed in high-level female handball players. The review of the scientific literature indicates that both modalities (isometric and concentric) are effective for strength development in sports (Lee, et al., 2018). However, isometric training would result in lower fatigue levels, making it advantageous in sports where frequent competition occurs, such as handball (Lum, et al., 2023). Furthermore, high-intensity isometric training, similar to that employed in the current study, has been associated with increased stiffness of the loaded tendons, resulting in a reduction of electromechanical delay and consequently increasing the rate of force development. Moreover, this regimen is posited to induce an expansion in the cross-sectional area of tendons, thereby mitigating the risk of injury during activities characterized by high-velocity dynamic stresses, such as shooting (Oranchuk, et al., 2019).

Regarding the relationship between maximum strength and shooting speed, the results of the current study did not always show consistency among the examined groups. This inconsistency could be linked to the small sample size. Despite this limitation, and recognizing the importance of interpreting the data with caution, significant positive correlations of moderate, high, and very high magnitude were observed between the 1MR value and throwing speed, both with and without accuracy. These findings strongly suggest the potential utility of both strength training modalities to improve performance in this skill.

In this regard, and as suggested by several studies (Bogdanis, et al., 2014; Bogdanis, et al., 2018; Duchateau & Hainaut, 2020; Lum, Barbosa, et al., 2022; Lum, Comfort, et al., 2022), isometric tension training can provide a powerful neuromuscular stimulus by improving specific aspects of motor coordination, including greater contraction speed and synchronization of muscle fibers. This would be related to positive adaptations at the excitation-contraction coupling level, particularly observed when the athlete aims to develop maximum strength in the shortest possible time (Fleck & Kraemer, 2017). Additionally, this type of stimulus is able to recruit more motor units with higher activation thresholds, thus increasing the chances of triggering post-activation potentiation (Martínez-García, et al., 2021). The purpose of performing medicine ball throws after the isometric stimulus was to take advantage of this potentiation of agonist muscles (Gilmore, et al., 2019; Krzysztofik, et al., 2022), which has been shown to be particularly effective in athletes with a high level of training, as was the case with the subjects in the current study (Ojeda, et al., 2016).

In the study by Raeder et al. (2015), conducted on competitive-level handball players, six weeks of training involving medicine ball throws (using 1 and 2 kg balls) resulted in significant improvements in shooting speed compared to the control group. In another study involving male handball players, but of shorter duration (four weeks), no improvements in shooting speed from 7m and 9m with jump were observed following training programs that included throwing medicine balls (1 kg), the official handball ball, or tennis balls (Ortega-Becerra, et al., 2019). However, in a study with an experimental intervention of similar duration to that of the present work (eight weeks vs. nine weeks, respectively) and with a sample of male players of the same sport, a beneficial effect on throwing speed was observed with training programs involving the throwing of medicine balls (3 kg), compared to similar programs that involved the throwing of regular handball balls. In this study, the shooting speed improved in standing, running, and jumping throws (Hermassi, et al., 2015).

The duration of the intervention in this work, as well as the combination of stimuli to which the players in the IG group were subjected (isometric tension followed by loaded throws, taking advantage of post-activation potentiation), could partially explain the significant improvement in the speed of the shots without aiming from 7m observed only in the IG group after the intervention. However, it is important to note that although there was a trend toward improvement in the analyzed capacities, most variables did not reach statistical significance in either the IG or DG group. The absence of a significant improvement in the observed performance could be partly attributed to the insufficient accumulated contraction time and weekly frequency used in this study. In this regard, Lum et al. (2019) suggest, for isometric strength training, a total contraction time of 30 to 90 seconds per session, while Fleck and Kraemer (2017) recommend a frequency of at least three sessions per week. Kanehisa et al. (2002) observed significant improvements in muscle volume, fascicular pennation angle, and torque production in elbow extensions after ten weeks of isometric training with sets of the same duration as in the present study (6s). However, these authors conducted 12 sets per session (totaling 72s of contraction), and the frequency was three sessions per week. In contrast, in this study, the total accumulated daily effort was only 24 seconds (four series of six seconds each), and the frequency was two sessions per week, below the recommended values.

In addition, applying isometric stimuli at various angles of the target joint could be more effective. Most studies indicate that this type of stimulus produces strength improvements, particularly within a range of joint angles close to that in which the effort was applied (± 5 to 30 degrees, depending on the muscle group and the considered movement), without necessarily leading to significant gains at other angles, especially when the total duration of isometric effort per session is not very prolonged. This phenomenon is known as the specificity of the joint angle (Fleck & Kraemer, 2017). In this study, isometric effort was performed only at two specific joint angles, with a possibly insufficient total duration per session to achieve significant transfer of adaptations to others.

The experimental intervention in this study lasted nine weeks. This period and the frequency employed (two sessions per week) might have been insufficient to elicit substantial adaptations in the variables under analysis. This aspect becomes particularly relevant when considering the high training level of the athletes, implying a lower margin for improvement (Fleck & Kraemer, 2017). Since previous training experience influences the adaptation margin within a training cycle (González, 2014), especially regarding isometric strength training, interventions of longer duration, even up to 24 weeks, have been suggested (Lum, et al., 2023). It is necessary to emphasize that the athletes were in the competitive season, and they would be expected to be close to their peak athletic form within the training macrocycle. This would consequently be associated with a lower potential for improvement. In this regard, it has been recommended that these types of studies be conducted in periods distant from competitions, particularly in experienced athletes (da Costa Alecrim, et al., 2020; Ortega-Becerra, et al., 2019; Raeder, et al., 2015).

Gilmore et al. (2019) investigated the acute effect of a high-intensity isometric potentiation warm-up in a female softball team. The authors suggest that there is a potentiation window for optimal performance after four to 12 minutes of recovery, peaking at six minutes. They understand this phenomenon could be related to the time required for mitochondrial resynthesis of phosphocreatine deposits. In the present study, on the contrary, medicine ball throws were carried out immediately after (without a pause) isometric or dynamic effort. Although the optimal time to achieve maximum post-activation potentiation (acute effect) does not necessarily indicate the optimal time for long-term improvements (chronic effect), it is possible to hypothesize that post-intervention performance could have been higher if a recovery pause had been employed before the throws. In this context, we consider it relevant to conduct future research examining the long-term impact of the pause in post-activation potentiation training (e.g., no pause versus a six-minute pause) on shooting speed.

Although the performance improvements after the intervention were lower than expected, both groups achieved comparable results through different strength training programs. It is worth noting that isometric training would present some additional practical advantages (Fleck & Kraemer, 2017). Among these, it stands out that, unlike dynamic training, it does not require quantification or progressive load adjustments, as all athletes exert their maximum effort in predefined positions. It also does not necessitate personalized weight dosages. We believe these practical advantages are particularly important in the dynamics of everyday training.

Finally, regarding the difference between shooting with aim and shooting without aim (table 3), the present study's findings align with what has been reported in various studies conducted with handball athletes. These works show that accuracy tends to decrease when the speed approaches its maximum (exceeds 80-90% of the maximum speed) (García, et al., 2013; Nuno, et al., 2016; Van den Tillaar & Ettema, 2003, 2006).

The present study had limitations, including the small number of athletes in the experimental groups and the absence of a control group. Additionally, the generated tension was not quantified during the isometric contraction effort. The lack of movement against a real weight might adversely affect the athlete's motivation, contradicting the application of maximum potential tension. Despite verbal encouragement and the athletes' commitment to training, it cannot be objectively ensured that each attempt was maximal, which could significantly impact the results achieved (Lum & Barbosa, 2019). Considering these factors, the results should be interpreted with caution.

Conclusions

Considering the importance of speed and accuracy in shooting to achieve maximum competitive performance in handball, the search for training strategies to enhance these aspects becomes relevant. In this regard, using dynamic horizontal pushing efforts followed by medicine ball throws under the conditions described in this study would not significantly improve performance in these variables. However, it might contribute to their maintenance. In addition, replacing horizontal pushing with an isometric effort of the same duration would lead to comparable, even slightly superior, results.

Given the practical advantages of isometric training over other strength training modalities, especially during group sessions, the findings of this study suggest that isometric training could be an efficient alternative for improving strength and shooting speed in handball and possibly in other sports. Future studies with longer intervention periods, incorporating isometric stimuli of varying durations and encompassing a broader range of joint angles, are recommended.

References

Asencio, P., Sabido, R., García-Valverde, A., & Hernández-Davó, J. (2020). Does handball throwing velocity increase after an eccentric overload-induced postactivation potentiation?. European Journal of Human Movement, 44, 5-18. https://doi.org/10.21134/eurjhm.2020.44.543

Bautista, I., Mampel, J.M., Baraja, L., & Martinez, I. (2021). Relación entre la potencia y velocidad en press de banca y la velocidad de lanzamiento de balón en jugadores profesionales de balonmano. Retos, 40, 53-59

Berning, J. M., Adams, K. J., DeBeliso, M., Sevene-Adams, P. G., Harris, C., & Stamford, B. A. (2010). Effect of functional isometric squats on vertical jump in trained and untrained men. Journal of Strength and Conditioning Research, 24(9), 2285–2289. https://doi.org/10.1519/JSC.0b013e3181e7ff9a

Bogdanis, G. C., Tsoukos, A., Methenitis, S. K., Selima, E., Veligekas, P., & Terzis, G. (2018). Effects of low volume isometric leg press complex training at two knee angles on force-angle relationship and rate of force development. European Journal of Sport Science, 19(3), 345–353. https://doi.org/10.1080/17461391.2018.1510989

Bogdanis, G. C., Tsoukos, A., Veligekas, P., Tsolakis, C., & Terzis, G. (2014). Effects of muscle action type with equal impulse of conditioning activity on postactivation potentiation. Journal of Strength and Conditioning Research, 28(9), 2521–2528. https://doi.org/10.1519/JSC.0000000000000444

Bompa, T. (2000). Periodización del entrenamiento deportivo (programas para obtener el máximo rendimiento en 35 deportes). Paidotribo.

Caycho, T., Ventura-León, J., & Castillo-Blanco, R. (2016). Effect size for the difference of two groups in health sciences. Anales del Sistema Sanitario de Navarra, 39(3), 459–461. https://doi.org/10.23938/ASSN.0242

Cohen, J. (1992). A power primer. Psychological Bulletin, 112(1), 155–159. https://doi.org/10.1037//0033-2909.112.1.155

Cometti, G. (2000). Los métodos modernos de musculación. (4th ed). Paidotribo.

Cherif, M., Chtourou, H., Souissi, N., Aouidet, A., & Chamari, K. (2016). Maximal power training induced different improvement in throwing velocity and muscle strength according to playing positions in elite male handball players. Biology of Sport, 33(4), 393–398.

Da Costa Alecrim, J., da Costa Alecrim Neto, J., Oliveira Souza, M., & Pivetta Pires, G. (2020). Efeitos do treinamento pliométrico e isométrico na força explosiva de membros superiores de atletas de Handebol. E-Balonmano.com: Revista de Ciencias del Deporte, 16(1), 49-54.

Dietz, C., & Peterson, B. (2012). Triphasic Training: A systematic approach to elite speed and explosive strength performance. Bye Dietz Sports Enterprise.

Duchateau, J., & Hainaut, K. (2020). Isometric or dynamic training: differential effects on mechanical properties of a human muscle. Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology, 56(2), 296–301. https://doi.org/10.1152/jappl.1984.56.2.296

Fleck, S., & Kraemer, W. (2017). Fundamentos do treinamento de força muscular. (4th ed). Artmed.

Garcia, J. A., Sabido, R., Barbado, D., & Moreno, F. J. (2013). Analysis of the relation between throwing speed and throwing accuracy in team-handball according to instruction. European Journal of Sport Science, 13(2), 149–154.

Gilmore, S. L., Brilla, L. R., Suprak, D. N., Chalmers, G. R., & Dahlquist, D. T. (2019). Effect of a High-Intensity Isometric Potentiating Warm-up on Bat Velocity. Journal of Strength and Conditioning Research, 33(1), 152–158. http://doi.org/10.1519/JSC.0000000000002855

Goss-Sampson, M. A., & Meneses, J. (2019). Análisis estadístico con JASP: Una guía para estudiantes. Barcelona: Universitat Oberta de Catalunya

Gómez-López, M., Angosto, S., López-Triviño, J., & Antúnez, A. (2021). Eficacia de los porteros de balonmano en los últimos mundiales absolutos masculino y femenino. E-balonmano.com, Revista de Ciencias del Deporte, 17(1), 13-22

González Badillo, J. (2014). Consideraciones sobre la Manifestación y el Desarrollo de la Fuerza y la Potencia Muscular. PubliCE. https://g-se.com/consideraciones-sobre-la-manifestacion-y-el-desarrollo-de-la-fuerza-y-la-potencia-muscular-799-sa-x57cfb271893a7

Gorostiaga, E. M., Granados, C., Ibáñez, J., & Izquierdo, M. (2005). Differences in physical fitness and throwing velocity among elite and amateur male handball players. International Journal of Sports Medicine, 26(3), 225–232. https://doi.org/10.1055/s- 2004-820974

Hatzimanouil, D. (2019). Throwing effectiveness per throwing area and playing position among high level handball players. Journal of Physical Education and Sport Management, 6(1), 13-20. https://doi.org/10.15640/jpesm.v6n1a2

Hernández-Sampieri, R., Fernández-Collado, C., & Baptista-Lucio, C. (2014). Metodología de la investigación. (6th ed). McGraw-Hill Education.

Hermassi, S., Van den Tillaar, R., Khlifa, R., Chelly, M. S., & Chamari, K. (2015). Comparison of In-Season-Specific Resistance vs. a Regular Throwing Training Program on Throwing Velocity, Anthropometry, and Power Performance in Elite Handball Players. Journal of Strength and Conditioning Research, 29(8), 2105–2114. https://doi.org/10.1519/JSC.0000000000000855

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Medicine and Science in Sports and Exercise, 41(1), 3–13. https://doi.org/ 10.1249/MSS.0b013e31818cb278

Kanehisa, H., Nagareda, H., Kawakami, Y., Akima, H., Masani, K., Kouzaki, M., & Fukunaga, T. (2002). Effects of equivolume isometric training programs comprising medium or high resistance on muscle size and strength. European journal of Applied Physiology, 87, 112-119. https://doi.org/10.1007/s00421-002-0604-6

Krzysztofik, M., Spieszny, M., Trybulski, R., Wilk, M., Pisz, A., Kolinger, D., Filip- Stachnik, A., & Stastny, P. (2023). Acute Effects of Isometric Conditioning Activity on the Viscoelastic Properties of Muscles and Sprint and Jumping Performance in Handball Players. Journal of Strength and Conditioning Research, 37(7), 1486–1494. https://doi.org/10.1519/JSC.0000000000004404

Laguna, M. (2019). Curso básico de Balonmano. Grupo Magro Editores.

Lee, S. E. K., Lira, C. A. B., Nouailhetas, V. L. A., Vancini, R. L., & Andrade, M. S. (2018). Do isometric, isotonic and/or isokinetic strength trainings produce different strength outcomes? Journal of Bodywork and Movement Therapies, 22(2), 430–437. https://doi.org/10.1016/j.jbmt.2017.08.001

Løken, J., Solstad, T. E. J., Stien, N., Andersen, V., & Saeterbakken, A. H. (2021). Effects of bouncing the barbell in bench press on throwing velocity and strength among handball players. PloS One, 16(11), e0260297. https://doi.org/10.1371/journal.pone.0260297

Lum, D., & Barbosa, T.M. (2019). Brief Review: Effects of Isometric Strength Training on Strength and Dynamic Performance. International Journal of Sports Medicine, 40(6), 363-375. https://doi.org/10.1055/a-0863-4539

Lum, D., Barbosa, T.M., Aziz, A.R., & Balasekaran, G. (2022). Effects of Isometric Strength and Plyometric Training on Running Performance: a Randomized Controlled Study. Research Quarterly for Exercise and Sport, 94, 263 - 271.

Lum, D., Comfort, P., Barbosa, T. M., & Balasekaran, G. (2022). Comparing the effects of plyometric and isometric strength training on dynamic and isometric force-time characteristics. Biology of Sport, 39(1), 189–197. https://doi.org/10.5114/biolsport.2022.103575

Lum, D., Joseph, R., Ong, K. Y., Tang, J. M., & Suchomel, T. J. (2023). Comparing the Effects of Long-Term vs. Periodic Inclusion of Isometric Strength Training on strength and Dynamic Performances. Journal of Strength and Conditioning Research, 37(2), 305–314. https://doi.org/10.1519/JSC.0000000000004276

Martínez-García, D., Rodríguez-Perea, Á., Huerta-Ojeda, Á., Jerez-Mayorga, D., Aguilar-Martínez, D., Chirosa-Rios, I., Ruiz-Fuentes, P., & Chirosa-Rios, L. J. (2021). Effects of Pre- Activation with Variable Intra-Repetition Resistance on Throwing Velocity in Female Handball Players: a Methodological Proposal. Journal of Human Kinetics, 77, 235–244. https://doi.org/10.2478/hukin-2021-0022

Mascarin, N. C., de Lira, C. A. B., Vancini, R. L., de Castro Pochini, A., da Silva, A. C., & Dos Santos Andrade, M. (2017). Strength Training Using Elastic Bands: Improvement of Muscle Power and Throwing Performance in Young Female Handball Players. Journal of Sport Rehabilitation, 26(3), 245–252. https://doi.org/10.1123/jsr.2015-0153

Milanović, D., Vuleta, D., & Ohnjec, K. (2018). Performance Indicators of Winning and Defeated Female Handball Teams in Matches of the 2012 Olympic Games Tournament. Journal of Human Kinetics, 64, 247–253. https://doi.org/10.1515/hukin-2017- 0198

Nuno, A., Chirosa, I. J., Van den Tillaar, R., Guisado, R., Martin, I., Martinez, I., & Chirosa, L. J. (2016). Effects of fatigue on throwing performance in experienced team handball players. Journal of Human Kinetics, 54(1), 103–113. https://doi.org/10.1515/hukin-2016-0039

Ojeda, Á. H., Maliqueo, S. G., López, J. C., Serrano, P. C., Campos, D. G., Retamal, D. S., & Caneo, L. A. (2019). Acute effect of an Intra-Set Variable Resistance of back squats on 30-m sprint times of elite woman athletes. Archivos de Medicina del Deporte, 36, 386–391.

Oranchuk, D. J., Storey, A. G., Nelson, A. R., & Cronin, J. B. (2019). Isometric training and long‐term adaptations: Effects of muscle length, intensity, and intent: A systematic review. Scandinavian Journal of Medicine & Science in Sports, 29(4), 484-503. https://doi.org/10.1111/sms.13375

Ortega-Becerra, M., Pareja-Blanco, F., Jiménez-Reyes, P., Cuadrado-Peñafiel, V., & González-Badillo, J. J. (2018). Determinant Factors of Physical Performance and Specific Throwing in Handball Players of Different Ages. Journal of Strength and Conditioning Research, 32(6), 1778–1786. https://doi.org/10.1519/JSC.0000000000002050

Ortega-Becerra, M., Sigüenza-Iglesias, J. A., & Asian-Clemente, J. (2019). Effects of 4- Week Training with Balls of Different Weights on Throwing Velocity in Handball Players. Journal of Physical Education and Sport, 19, 344-349. https://doi.org/10.7752/jpes.2019.s2051

Raeder, C., Fernandez-Fernandez, J., & Ferrauti, A. (2015). Effects of Six Weeks of Medicine Ball Training on Throwing Velocity, Throwing Precision, and Isokinetic Strength of Shoulder Rotators in Female Handball Players. Journal of Strength and Conditioning Research, 29(7), 1904–1914. https://doi.org/10.1519/JSC.0000000000000847

Schwesig, R., Hermassi, S., Wagner, H., Fischer, D., Fieseler, G., Molitor, T., & Delank, K. S. (2016). Relationship Between the Range of Motion and Isometric Strength of Elbow and Shoulder Joints and Ball Velocity in Women Team Handball Players. Journal of Strength and Conditioning Research, 30(12), 3428–3435. https://doi.org/10.1519/JSC.0000000000001450

Van den Tillaar, R. (2020). The Effects of Target Location Upon Throwing Velocity and Accuracy in Experienced Female Handball Players. Frontiers in Psychology, 11, 1-6. https://doi.org/10.3389/fpsyg.2020.02006

Van den Tillaar, R., & Ettema, G. (2006). A comparison between novices and experts of the velocity-accuracy trade-off in overarm throwing. Perceptual and Motor Skills, 103(2), 503–514. https://doi.org/10.2466/pms.103.2.503-514

Van den Tillaar, R., & Ettema, G. (2003). Instructions emphasizing velocity, accuracy, or both in performance and kinematics of overarm throwing by experienced team handball players. Perceptual and Motor Skills, 97(3), 731–742. https://doi.org/10.2466/pms.2003.97.3.73

Vila, H., Zapardiel, J.C., & Ferragut, C. (2020). The relationship between effectiveness and throwing velocity in a handball match. International Journal of Performance Analysis in Sport, 20, 180 - 188.

Wagner, H., Fuchs, P. X., & von Duvillard, S. P. (2018). Specific physiological and biomechanical performance in elite, sub-elite and in non-elite male team handball players. The Journal of Sports Medicine and Physical Fitness, 58(2), 73–81. https://doi.org/10.23736/S0022-4707.16.06758-X

Zapardiel, C., Vila, H., Abraldes, J.A., Manchado, C., & Ferragut, C. (2017). Analysis of the throwing speed in the different positions in the field during the competition. Journal of Human Sport and Exercise, 12, S882-S891. https://doi.org/10.14198/jhse.2017.12.Proc3.12

Zhelyazkov, T. (2019). Bases del entrenamiento deportivo. Paidotribo

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