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Enhancing Performance and Promoting Sustainability in Female Handball: The Impact of Olympic Movement Training on Jumping, Throwing, Sprinting, and Change of Direction

Estela Orduña-Borraz [1], Elena Mainer-Pardos [1,*], Luis Alberto Marco-Contreras [1] and Demetrio Lozano-Jarque [1]

[1] Universidad San Jorge, Autov A23 km 299, 50830 Villanueva de Gállego, (Zaragoza), Spain; eorduña@usj.es; epardos@usj.es; lamarco@usj.es; dlozano@usj.es

* Correspondence: epardos@usj.es

Abstract: Improving performance and promoting sustainability in women's handball are key objectives to maximize the potential of female players and ensure the long-term viability of the sport. In this context, training with Olympic movements and their derivatives improves the development of strength, power, and speed, which are determinants of performance in team sports. The aim of this study was to determine if training with Olympic movements produces significant improvements in jumping, throwing, sprinting, and change of direction performance in women handball players. Twenty-one female handball players participated in the study (10 for the control group and 11 for the intervention group). Age ranged from 15 to 17 years. All participants performed four assessment tests (Abalakov Test, throw test, 20-meter Sprint and V-Cut Test) to determine jump height, throwing speed, running speed, and change of direction ability. Measurements were carried out before and after the intervention. For six weeks, the control group performed the strength work established by the club twice a week while the intervention group additionally performed training with Olympic movements. Significant differences ($p < 0.05$) were found between the pre and post measurement of the control group and the intervention group in jump height, throwing speed and running speed, being higher in the intervention group. For the change of direction, no significant differences were found. Between groups, significant differences were observed at the end of the intervention for jump height and running speed. The conclusion of this study was that, by training with Olympic movements, in addition to regular training, could produce greater improvements in jumping performance, throwing speed and running speed in female handball players.

Keywords: weightlifting; training; strength; power; team sports

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1. Introduction

Handball is a collective sport of collaboration– opposition, of intermittent nature, in which high-intensity actions are combined and primarily involve physical contact [1,2]. This sport stands out for the performance of repeated actions such as throws, changes of direction (COD), and jumps [3]. Success in handball is determined by a series of technical, tactical, and psychological aspects, anthropometric characteristics [4], and physiological attributes [5,6].

The throw is the most important action for the achievement of success in handball [2,7], as the efficiency of this gesture has a high influence on the final result [8] and discriminates between winning and losing teams [9,10]. Both high velocity and good accuracy are two of the most important determinants of a successful pitch [7,11]. Throwing speed is one of the most important factors in goal scoring [12] because an increase in throwing speed decreases the visual information for the goalkeeper, thus providing an advantage for the thrower [13,14]. Furthermore, the achievement of high velocity depends on technique, coordination of different body segments, and muscle power [15].

Lower extremity power is a performance indicator for athletes performing triple extension (hip, knee and ankle) [16]. In the case of handball, actions such as jumping, sprinting and changing

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direction involve this triple extension and require applying the greatest possible force for a short period of time [17]. Regarding the relationship between general and specific throwing tests, several studies show a moderate correlation (r>0.60) between muscular strength, power, and throwing speed [18,19] in handball players, being higher (r=0.80) in female handball players than in male counterparts [2]. The existence of a relationship between throwing velocity and maximal strength in bench press has also been demonstrated [20] along with the relationship between throwing velocity and isokinetic upper body strength [21]. In contrast, some authors found no correlation between throwing velocity and isokinetic muscle strength in the internal and external rotators of the shoulder [22–24].

Running speed is mainly determinant for wingers, since most of the distance they cover is done by running at high speed (> 5.0 m-s-1): 410.3 ± 193.2 m, and by sprinting (> 6.7 m-s-1): 98.0 ± 75.4 m [34], also accumulating most of the team sprints, in the counterattacking phase [25]. According to Manchado et al. (2013), the total distance covered during a match is 4,614 m (2,066 m for goalkeepers and 5,251 m for outfield players), divided into 9.2 % sprinting, 26.7 % fast running, 28.8 % slow running and 35.5 % walking [25]. In addition, significant differences were found in the type of movement when in the defense phase compared to the attack phase, both walking (+20%; $p < 0.000$; Cohen's effect size (ES) = 1.01), at a jogging intensity (29.6%; $p = 0.000$; ES = 0.90), and high intensity running (+ 25.2%; $p = 0.077$; ES = 0.31) [26].

Jumping ability is also an important performance indicator [27–29], mainly for wingers, as they usually perform more jumping throws to overcome opponents [30,31]. Furthermore, lower extremity strength is strongly related to throwing velocity [4]. Although there seems to be disagreement on whether jump height is a discriminant factor for professional matches, some studies have found that there are differences between jumping measures depending on the level of the players. In contrast, Wagner et al. (2014) found no significant differences in jump height between professional and amateur players [31]. Other studies consider jumping ability a performance factor by allowing an increase of time in the decision making of the jump shot or jump pass [27,28].

Finally, the COD [30] is an action that consists of chaining an acceleration with a deceleration to continue with an acceleration in a different direction [32] as the front manoeuvre, which is the most recurrent action in handball to overcome an opponent. Players need to generate a large amount of force in a short period of time to perform a quick COD [33], with those with larger angles requiring more force [30,34]

All these factors have one thing in common: they are directly related to one aspect of physical fitness, strength. Therefore, aspects such as jumping ability and COD are related and are sometimes used as predictors [35].

Regarding the training methods used to develop the indicated capacities, physical preparation in handball has followed the same pattern for many years, with traditional strength training as its basis. In this type of physical preparation, a routine of weights, circuit training, strength exercises with specific gestures, plyometrics, etc., is usually performed in which work is done with high levels of load but at low speed. Currently, it is considered necessary to include in this section of the training the performance of Olympic movements or their derivatives, since, with these, in addition to working with high levels of load, we also work with high speeds, probably more suitable for the development of strength, power, and speed in team sports [20].

On the other hand, plyometrics, sprints, swing platform, and kettlebell training can help improve lower extremity strength and power [16], but there is also other research claiming that weightlifting can provide a superior training stimulus [36]. This type of training includes movements such as Clean, Jerk, and Snatch and their derivatives. These exercises are mainly used to train lower body muscle power. Some studies claim that there is a relationship between the performance of Olympic movements and running speed, vertical jump, and COD [16]. According to another study conducted with female handball players, training with Olympic movements produces greater improvements in sprint performance and lower extremity strength compared with traditional strength training [36,37].

Olympic movements, in addition to favouring the development of power, have positive effects on aerobic and anaerobic metabolism, balance and flexibility. These exercises are related to increased bone density and muscular adaptations; therefore, their use could be very useful in injury prevention, provided they are taught and supervised by a qualified professional [36]. The major drawback of training with Olympic movements is their high technical demand, as it would take a long time to teach them to athletes who do not practise weightlifting regularly. Therefore, it is considered more appropriate to work with exercises that involve less technical complexity and lower levels of mobility and stability. These derived movements can be hanging, power or performed unilaterally, as they are also effective in improving force production per unit time [16].

In addition to the technical and physical aspects of handball, it is essential to consider sustainability in the sport context. Handball, as a sport that requires efficient coordination of physical and tactical resources, can serve as a model for understanding sustainability in human activity [38]. Efficient energy management and optimisation of physical performance in handball reflect key principles of sustainability, such as resource efficiency and minimisation of environmental impact [39]. At the same time, the promotion of sustainable practises in sport, such as the use of environmentally friendly materials and long-term health and wellness, aligns with global sustainable development goals [40].

The current study aims to provide a comprehensive analysis of the impact of Olympic movements on the performance of handball players, specifically focusing on improvements in jumping, throwing, sprinting, and COD. At the same time, this research aims to explore the broader context of handball as a sport activity that not only demands physical excellence, but also aligns with sustainable practices and principles. By examining the intersection of sport training, in particular Olympic movements in handball, with aspects of health and sustainability, this study aims to provide a unique perspective on how the discipline of handball contributes to sustainability. This dual focus will provide valuable insights into both the specific physical training techniques that optimize handball performance and the broader implications of these practices in the context of sustainable sport and health. We hypothesise that strength training incorporating Olympic movements will significantly improve handball performance variables such as jumping, throwing, sprinting and COD. In addition, this training will promote sustainable practises in the sport, reflecting resource-efficient principles and minimising environmental impact. We anticipate that players using these training methods will not only improve their athletic performance but also adopt a more sustainable and holistic approach to overall health and wellness.

2. Materials and Methods

The study design was randomized controlled, with a parallel design, a control group (CG) and an experimental group (EG).

Participants

Twenty-one amateur female handball players participated in the study. All the subjects played in the under-16 (n=11) or under-18 (n=10) teams of the Balonmano La Jota, Zaragoza, Spain. Participants were divided into two groups according to the ABK test and randomised with the ABBA sequence. The CG (n=10) consisted of five players under-16 and five players under-18, and the experimental group (n=11), consisted of six players U-16 and five players U-18. The age of the subjects was 15.76 ± 0.63 years, the height was 163.05 ± 4.08 centimeters, and the weight was 58.05 ± 6.82 kilograms.

The choice of categories for conducting the study is due to the fact that adolescence is identified as the ideal time to provoke more and new stimuli [41]. The players who were part of the study had at least three years of experience playing handball, had never trained with Olympic movements, did not suffer from any injury or pathology that would prevent them from the correct development of the intervention and possessed adequate physical condition. Before the start of the study, all participants were informed of the basic characteristics of the research and of the possible risks related to the execution of the tests. All subjects signed a consent form. The study was conducted in accordance with the Helsinki Declaration and approved by a local ethical committee of the Universidad San Jorge de Zaragoza (Spain) and CEICA committee of Aragón (Spain) nº PI23-141.

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Procedures

All the tests were preceded by a warm-up, which consisted, first of all, of performing different types of movements across half of the handball court. The movements were jogging forward, jogging while doing shoulder mobility, skipping, lateral movement, strides, three steps and a jump, three steps and a COD and 10 squats on the spot followed by a sprint. Secondly, goal kicks were performed in support and then in jumping.

Each of the assessment tests were carried out on different days and the players were instructed to perform them at maximum intensity. For each test they had two attempts, separated by a time of two minutes to ensure full recovery, from which the best results were taken as a reference.

Abalakov's Test (ABK). Jump height was assessed using the Abalakov Test and measured in centimeters (cm). This test was performed on the ADR jumping platform. The athletes were instructed to perform a vertical jump with a knee flexion of 90° with the help of the arms being able to use them freely and keeping the trunk as straight as possible. This test begins with the athlete standing, then the knees are flexed to 90º and finally the extension of the lower limbs and the movement of the arms are performed (González & Garrido, 2004).

Throwing to goal. To determine the throwing speed, the players were asked to throw in support from the 7-metre line to an empty goal and at maximum intensity, following the rules of this throw as stated in the handball regulations [42]. The throwing speed was obtained using a high-performance sports radar (Stalker Pro 2 Radar Gun, Applied Concepts, Inc./Stalker Radar, Texas, USA) placed at the 9-meter line, behind the player throwing the ball, and pointing to the executing arm. Only throws that entered directly into the goal, without touching the ground, were considered as valid. Molten official handballs (Molten Corp., Hiroshima, Japan) were used, (circumference: 54-56 cm; weight: 325-375 g).

Sprint 20 metres. To assess running speed, players were asked to perform a 20-metre sprint in a straight line to obtain the speed in metres/second (m/s). This distance was used as it was the closest to the average obtained during a handball match (18 ± 6.91 metres) [43]. The athletes performed the sprint taking as references the finish line at the beginning of the sprint and the center line for the end. The times were measured with double beam photocell systems (Witty, Microgate, Bolzano, Italy) placed at 1 m above ground level at the above-mentioned marks. above ground level at the aforementioned marks. All participants started standing once ready and 0.5 m behind the first photocell.

V-Cut Test. To obtain the results on the ability to change direction, the V-Cut Test was used, in which the players covered 25 metres making four changes of direction (one every five metres) with an exit angle of 45º (Gonzalo-Skok et al., 2015). Using double beam photocell systems (Witty, Microgate, Bolzano, Italy), the seconds (s) taken by each player to perform the test were obtained accurately.

Once the data for all variables had been collected, the intervention began, lasting six weeks, which was sufficient time to observe improvements in performance in aspects related to team sports [44].

The CG carried out the strength training sessions proposed by the team on Mondays and Wednesdays, prior to the track training. A standard warm-up consisting of jogging, joint mobility, squats, lunges, push-ups with knees and rowing with rubber bands was performed before the start of training.

Monday's training consists of four blocks. Each block consists of two main exercises, one compensatory exercise and one transfer exercise. The players performed eight repetitions of the first main exercise, eight repetitions of the second main exercise, six repetitions of the compensatory exercise and four repetitions of the transfer exercise. This sequence was repeated twice more for a total of three sets. Once the first block was completed, we moved on to the next. The players were distributed equally in each block as there was not enough material to perform them all in the same order.

Wednesday's training is made up of five blocks, the last one being abdominal work. The first four blocks consist of a general exercise, a targeted exercise and a specific exercise. In the Core block

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there are three abdominal exercises. The players performed eight repetitions of the general exercise, four repetitions of the targeted exercise and four repetitions of the specific exercise. This sequence was repeated two more times for a total of three sets. Once the first block was completed, they moved on to the next. As in the Monday training session, the players were divided equally between the first four blocks and finally performed the Core block all together.

The intensity at which the players performed the exercises at which the load could be regulated was 75% of their maximum repetition (MR). In both training sessions, if the exercise was unilateral, the repetitions indicated in the table had to be performed with each limb. These training sessions are detailed in Table 1 and Table 2.

Each assessment test took place on different days and the players were instructed to perform it at maximum intensity. For each test, there were two attempts, separated by a time limit of two minutes, and the best results were used as a reference.

The players who were part of the intervention group were taught the Olympic movements that the training sessions consisted of with pikes and eight-kilogram bars.

Once the data for all variables were collected, the intervention began, which lasted six weeks, enough time to observe improvements in performance in aspects related to team sports [44]. The control group carried out the strength training proposed by the club for Mondays and Wednesdays, prior to the track training. These workouts are detailed in Table 1 and Table 2.

Table 1. Monday's strength training.

3 Sets 75%MR[1]	**Main 8 repetitions**	**Compensatory 6 repetitions**	**Transfer 4 repetitions**
Block 1	TRX Squat Lateral lunge	Monster walks	Unilateral hurdle jumps
Block 2	Bench Press Pull over	Shoulder press	Throwing to goal
Block 3	Hip thrust Snatch unilateral	Isometrics adductor with a fit ball	Forward and backward jumps
Block 4	TRX openings Assisted Pull up	Face pull	1vs1

[1] Maximum repetitions.

Table 2. Wednesday's strength training.

3 Sets 75%MR[1]	**Main 8 repetitions**	**Compensatory 6 repetitions**	**Transfer 4 repetitions**
Block 1	Bulgarian Squat	Jump over hurdles with feet together	Hurdle jump + sidestep + throw
Block 2	Landmine	Chest passes with a 3-kg ball	1 vs 1
Block 3	Hip thrust	Zigzag changes of direction	Wide lunges
Block 4	Face pull	Unilateral pull-up	Unilateral pulldown
Core	Dead bug	Lateral plank 30″	Front plank 30″

[1] Maximum repetitions.

The intervention group, in addition to executing the strength training proposed by the club, performed an additional Olympic movement training. For each proposed exercise, the participants had to perform three sets of eight repetitions with a rest of one minute between sets and two minutes between exercises. The intensity varied from 20% of their body weight to 30%. In the first two weeks

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of the intervention, corresponding to the first four sessions, an intensity of 20% of each player's body weight was used. In the four subsequent sessions, an intensity of 25% of their body weight was used. In the last four sessions, the training was carried out with an intensity of 30% of their body weight. The players were instructed that the movements should be performed at maximum speed.

Once the intervention period was over, all players, both CG and EG, underwent the four assessment tests again.

Statistical analysis

SPSS 28 software was used to perform the data analysis. Descriptive statistics of mean and standard deviation were calculated for age, height and weight. The same descriptive statistics were calculated for the variables of jump height, throwing speed, running speed and COD ability as a function of group (control or intervention) and as a function of the time of data collection (pre-intervention or post-intervention). To calculate whether the distribution of the variables is normal or not, Shapiro-Wilk was used. To compare the evolution of the variables throughout the intervention in the same group, Student's t test was used for related samples if the distribution was normal and Wilcoxon when the distribution was not normal. To compare the variables between the control group and the intervention group at the end of the intervention, Student's t test was used for independent samples if the distribution was normal and Mann-Whitney U if the distribution was not normal. All tests were performed at a significance level of less than 0.05 ($p < 0.05$). Cohen's d was used to assess the effect size. This author indicates that values lower than 0.20 show no effect, from 0.21 to 0.49 have a small effect, from 0.50 to 0.70 show a moderate effect and values equal to or higher than 0.80 show a large effect [45].

3. Results

Table 5 shows the results obtained for all the variables analysed.

Table 5. Effect size and percentage differences of all variables.

	Groups	PreTest	PostTest	ES Cohen	%
ABK Test *	CG	30.07 ± 4.09	31.2 ± 4.04*	0.29	3.96%
	EG	32.97 ± 3.01	35.3 ± 2.84*	0.82	7.25%
Throw	CG	51.71 ± 6.44	52.1 ± 6.40*	0.05	0.60%
	EG	50.35 ± 4.23	51.1 ± 4.29**	0.18	1.49%
Sprint 20 m	CG	4.61 ± 0.47	4.74 ± 0.47*	0.28	2.82%
	EG	4.72 ± 0.53	6.07 ± 0.28$	3.19	28.6%
V-Cut Test	CG	8.65 ± 0.44	8.50 ± 0.45**	0.34	1.73%
	EG	8.40 ± 0.46	8.22 ± 0.51**	0.37	2.14%

* ABK: Abalakov jump test; CG: Control group; EG: Experimental group; ES: Effect size; Level of significance: * = $p < 0.01$; ** = $p < 0.001$.

Jump height

Using the Wilcoxon test, significant differences were obtained between the CG at PRE and POST ($p < 0.01$) and the effect size was small ($d = 0.29$). The Student's t-test for related samples showed significant differences between the EG at PRE and POST ($p < 0.001$) and the effect size was large ($d = 0.82$). Using Student's t-test for independent samples, no significant differences were observed between CG and EG at PRE ($p > 0.05$). Using the Mann-Whitney U test, significant differences were observed between CG and EG at POST ($p < 0.05$).

Throwing velocity

Using Student's t-test for related samples, significant differences were obtained between CG at PRE and POST ($p < 0.01$) and there was no effect ($d = 0.05$). Using the same test, significant differences were observed between the EG at PRE and POST ($p < 0.001$) and there was also no effect ($d = 0.18$).

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With the Student's t-test for independent samples, no significant differences were observed between the CG and the EG in the PRE ($p > 0.05$) or between the CG and the EG in the POST ($p > 0.05$).

Running speed

Using Student's t-test for related samples, significant differences were obtained between the CG at PRE and POST ($p < 0.01$) and the effect size was small ($d = 0.28$). Using the same test, significant differences were observed between EG at PRE and POST ($p < 0.001$) and the effect size was large ($d = 3.19$). With Student's t-test for independent samples, no significant differences were observed between CG and EG at PRE ($p > 0.05$) but significant differences were observed between CG and EG at POST ($p < 0.001$).

Ability to change direction

The Student's t-test for related samples showed significant differences between CG at PRE and POST ($p < 0.001$) and the effect size was small ($d = 0.34$). Using the same test, significant differences were observed between EG at PRE and POST ($p < 0.001$) and the effect size was also small ($d = 0.37$). Using Student's t-test for independent samples, no significant differences were observed between CG and EG at PRE ($p > 0.05$) and between CG and EG at POST ($p > 0.05$).

4. Discussion

The aim of the study was to determine whether training with Olympic movements produces significant improvements in jumping, throwing, sprinting and COD performance in handball players through different assessment tests such as the Abalakov Test, penalty shootout, 20-metre sprint and V-Cut Test. According to the results obtained, it can be observed that both in the CG and in the EG there are significant differences at the end of the six weeks of training for each of the variables. Although there were improvements in both groups, the EG improved more than the CG in the variables jump height ($d = 0.82$), throwing speed ($d = 0.18$), running speed ($d = 3.19$) and ability to change direction ($d = 0.37$). Regarding the differences between groups, these occurred for the jump height and running speed variables, with better results being obtained in the EG. The following results confirm that the integration of Olympic movements into strength training has a positive and significant impact on performance variables in handball players, including notable improvements in jumping, throwing, sprinting, and COD. These results not only underscore the effectiveness of Olympic movements in improving physical skill in handball but also demonstrate their alignment with sustainable practises in sport.

In relation to our findings on jump height, the results of this study corroborate previous authors' claims about the strong relationship between training with Olympic movements and vertical jump performance [28,46]. We found that these movements significantly improve jump height, surpassing the improvements achieved with traditional training [20], especially in jumps such as the countermovement jump and the squat jump. This effect is attributed to better recruitment and control of motor units, leading to increased force per unit time and more efficient energy transfer across different body segments [47,48]. Furthermore, our results extend this understanding by demonstrating that training with Olympic movements not only improves jump height but also significantly optimizes other handball performance variables, such as throwing speed, running speed, and COD [48]. These results emphasise the relevance of Olympic movements not only for the development of specific physical skills but also for their contribution to a more holistic and sustainable approach to sport practice [35,49].

Our findings are in line with previous studies demonstrating the efficacy of Olympic movement training in improving athletic performance. Morris et al. (2022), compared strength and power between powerlifters, Olympic lifters, and sprinters, observing that the Olympic lifters group showed significantly higher peaks in strength, power, and jump height than the other groups [36]. Other studies found that athletes with better performance in exercises such as the Hang Power Clean, Hang Clean, and Hang Snatch achieved superior and significant results in jumping performance, exhibiting

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higher levels of peak strength and power ($p \leq 0.01$) [50]. This aligns with the findings, who noted that Olympic weightlifting training alone is effective for improving sprint speed and power, potentially enhancing strength and power when combined with vertical jump training [36]. However, it is crucial to note that there are studies that found no improvements in strength and power through Olympic movement training in jumping performance (d = -0.62) [51]. This discrepancy underscores the complexity of the impact of Olympic movement training and the need to consider individual and contextual factors to assess its efficacy. In our study, significant improvements in jump height, throwing velocity, sprint velocity, and COD ability among groups trained with Olympic movements support the hypothesis that such training is effective, although there may be variations in the response to training depending on the context and individual athlete characteristics. Indeed, as noted by Helland et al. (2017)[52], motorised strength and power training can be equally or more effective than free weight training in improving muscle power, jump height, and sprinting capacity compared with Olympic-style weightlifting, highlighting the importance of training method diversity.

In terms of the results obtained for throwing velocity, the existing literature supports the use of Olympic movements with throwing athletes. Players who have trained in exercises such as the Snatch and Clean & Jerk for more than two years are more likely to see improvements in strength and power in throwing activities. This could be justified by the mechanical similarity of the joints [37]. Several studies have concluded that there is a relationship between Olympic movements and increases in muscle volume, maximal upper limb strength and throwing velocity in handball players [19,37]. Therefore, the results obtained in this study regarding running speed align with several articles in which a relationship has been observed between the strength improvement obtained in the performance of Olympic movements and running speed, both in the 10-m sprint ($p < 0.05$) and the 30-m sprint [37,52]. These findings highlight the importance of incorporating Olympic movements into handball training, not only to improve specific aspects of sport performance but also to align with sustainable practises that promote the athlete's overall health and well-being [18].

When comparing training with Olympic movements and plyometric training, studies show that Olympic movements provide greater improvements in the five-meter and 20-meter sprints because of their emphasis on force production per unit time [47,48]. These results align with other studies indicating that athletes with greater performance in Olympic movements perform better in the 20-m sprint ($p < 0.01$) and over longer distances, so it is reasonable to assume that these results can be extrapolated to athletes whose disciplines require power, strength, and speed [36]. In contrast, studies such as those by Marković et al. (2007)[53]and Booth and Orr (2016)[54]did not observe significant improvements in 36-m sprints ($p > 0.05$) when comparing training with Olympic lifts, traditional strength training, and agility and speed training, which could differ from those obtained in the present study when using a different Olympic lifting program than the one proposed, since it involves very high loads, in addition to evaluating a much longer sprint distance.

Our results reinforce the idea that training with Olympic movements is especially beneficial for improving performance in short-distance sprint events, as demonstrated by improvements in sprint speed and COD ability in handball players [55]. These results suggest that although Olympic movement training may not be as effective for longer sprint distances, its impact on shorter distances and other performance variables is significant and aligns with sustainable training practises by promoting holistic and healthy physical development for athletes.

The results obtained in relation to the COD agree with those reported in the literature. According to several studies, training with Olympic movements does not produce significant differences ($p > 0.05$) compared with other groups in the COD. This could be because power transfer for this type of test is very complex, and the results could also be influenced by motor control factors. Another reason could be related to decision making regarding how much and when to accelerate and decelerate. However, studies such as those by Freitas et al. (2019) [56] suggest that stronger and more powerful athletes do not necessarily show greater COD ability, indicating that current strength and power training practises may not be optimal for improving this ability. Nevertheless, our findings show an improvement in the COD ability in the EG, suggesting that although Olympic movement training may not have a significant impact compared with other training methods, it may still contribute to

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improvements in this area. Differences in results between this study and others could be due to variations in training protocols, participant characteristics, or the specificity of the exercises used [57]. These results underline the importance of considering a comprehensive and personalised approach when training changes in direction in handball, considering not only strength and power but also factors such as motor control and tactical decision making [58].

Although the study provides positive results on the efficacy of training with Olympic movements in handball players, but there are some limitations that should be considered. Such as the lack of control group of untrained subjects. The study compares two groups (CG and GE) that received training but does not include a control group that did not receive any training. The absence of an untrained control group makes it difficult to assess whether the observed improvements are specific to Olympic movement training or simply a result of regular physical activity. On the other hand, the duration of the study was six weeks. Such a short period may not be sufficient to fully observe the long-term effects of training. A longer study duration would allow a better assessment of the sustainability of the improvements and whether they persist over time. Similarly, the sustainability measures show that the results are aligned with sustainable practices in sport, but the study does not provide specific measures of sustainability, nor does it assess how long-term implementation of this type of training might affect sustainable aspects in the sport context.

Based on the results obtained in the current study, as well as the limitations identified, several future lines of research could be proposed to further explore the topic. Conducting a longer-term study to evaluate its effects would allow a better understanding of the sustainability of the observed improvements and their persistence over time. Other training methods commonly used in handball could also be compared. This could include comparisons with traditional strength training, neuromuscular or plyometric exercises. It could also be explored how the integration of different types of strength training can improve other aspects of training, such as handball specific technique, tactical work and general physical conditioning. Finally, the possibility of adapting the Olympic movement training protocol for different ability levels and ages could be investigated, ensuring its sustainable applicability in a variety of contexts.

5. Conclusions

This study demonstrates that the incorporation of Olympic-derived movements into traditional strength training significantly improves the performance of U-16 and U-18 amateur handball players, specifically in jumping, throwing, and sprinting speeds. The use of lighter weights (20%-30% of body weight) twice a week from an early age has been found to be effective, producing substantial improvements in vertical jump, throwing, and sprinting. These results show that such training strategies are not only beneficial for sports that share similar performance factors as handball but also align with sustainable sports practises that promote holistic and health-focused physical development in young athletes.

Based on these results, it is recommended that strength training with Olympic movements and/or their derivatives be an integral part of physical preparation in handball to increase athletes' strength and power levels, thereby improving key performance factors such as jumping, throwing, and sprinting. Coaches should adapt loading intensities according to the initial competence of their athletes in Olympic movements, considering the actual demands of the sport. It is advisable to incorporate training with Olympic movements and/or their derivatives using light loads from an early age, with a frequency of twice a week. Overall, the training should adopt a holistic approach, focusing on improving strength and power while simultaneously working on essential handball abilities such as jumping, throwing, sprinting, and changing direction.

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