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The effects of a high intensity resistance and eccentric strength training program on the performance of handball players

Los efectos de un programa de entrenamiento de resistencia de alta intensidad y fuerza excéntrica en el rendimiento de jugadores de balonmano

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Abstract. This study aimed to was to determine the effect of interval and resistance training with a focus on the eccentric phase on the cardiovascular fitness and strength of elite handball players. Thirty handball players were recruited and randomly divided into two groups: an experimental group (age= 20.93±1.70; weight= 78.20±4.58; height= 178.26±3.86) and a control group (age= 21.40±1.76; weight= 77.64±5.92; height= 176.87±4.43). The variables of this study were muscle strength and stamina, power, and cardiovascular fitness. They were assessed by chest press test, push-up, medicine ball throw test, and the Cooper Test, respectively. The training program took place over 12 weeks, with five sessions per week, consisting of two aerobic exercises, and three muscular resistance training exercises focused on the eccentric phase. To analyze the effect of training, a paired sample t-test was employed. The results of this study showed that there were significant pre- to post-test differences in muscle strength (p=0.001), muscle stamina (p=0.001), muscle power (p=0.001), and cardiovascular fitness (p=0.001). The results of the present study indicated that a 12-week eccentric-focused interval and resistance training program improved the strength, stamina, power, and cardiovascular fitness of elite handball players.
Keywords: Interval training, Push up Test, medicine ball throw, preseason.

Resumen. El objetivo de este estudio fue determinar el efecto del entrenamiento interválico y de fuerza con un enfoque en la fase excéntrica sobre la aptitud cardiovascular y la fuerza de los jugadores de balonmano de élite. Treinta jugadores de balonmano fueron reclutados y divididos aleatoriamente en dos grupos, uno experimental (edad= 20,93±1,70; peso= 78,20±4,58; altura= 178,26±3,86) y un grupo control (edad= 21,40±1,76; peso= 77,64±5,92; altura= 176,87±4,43). Las variables de este estudio fueron la fuerza y resistencia muscular, la potencia y la aptitud cardiovascular. Fueron evaluados mediante la prueba de presión de pecho, lagartija, prueba de lanzamiento de balón medicinal y la prueba de Cooper, respectivamente. El programa de entrenamiento incluyó 12 semanas, cinco sesiones por semana, dos ejercicios aeróbicos y tres entrenamientos de resistencia muscular enfocados en la fase excéntrica. Para analizar el efecto del entrenamiento, se empleó una prueba t de muestras pareadas. Los resultados de este estudio mostraron que hubo diferencias significativas antes y después de la prueba en la fuerza muscular (p = 0,001), la resistencia muscular (p = 0,001), la potencia muscular (p = 0,001) y la aptitud cardiovascular (p = 0,001). Los resultados del presente estudio indicaron que un programa de entrenamiento de resistencia y de intervalos centrado en la fase excéntrica de 12 semanas mejoró la fuerza, la resistencia, la potencia y la aptitud cardiovascular de los jugadores de balonmano de élite.
Palabras claves: Entrenamiento interválico, Push up Test, lanzamiento de balón medicinal, pretemporada.

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Introduction

In the constant quest to optimize training and improve athletes′ performance, strength training is necessary (Martins, 2023). In recent years, numerous investigations have presented diverse strength training proposals aimed at increasing the performance of handball players (Cuevas-Aburto et al., 2020; Hermassi et al., 2017; Hermassi, Chelly, Bragazzi, Shephard, & Schwesig, 2019; Sabido, Hernández-Davó, Botella, & Moya, 2016) where different methodologies have been proposed with heterogeneous samples, whilst obtaining similar results (improvement or strength gain).

Despite the known benefits of resistance exercise, there is much to be understood regarding implementing eccentric exercise in these individuals. For example, although empirical evidence supporting its application is currently limited, but eccentric exercise is considered necessary for youth athletes (Drury et al., 2021). Moreover, because a greater volume of exercise can be done at less metabolic and cardiorespiratory cost, eccentric muscle work constitutes a promising training strategy, not only to improve athletes' performances but also to help maintain or restore the exercise capacity and quality of life in individuals with reduced tolerance for physical activity (Hody, Croisier, Bury, Rogister, & Leprince, 2019).

There is increasing evidence that chronic eccentric resistance training results in more significant improvements in power, strength, and stretch-shortening cycle function (i.e., eccentric/concentric function) when compared to traditional resistance training (Chaabene et al., 2020; Douglas, Pearson, Ross, & McGuigan, 2017a; Elmer, Steven, Hahn, McAllister, Leong, & Martin, 2012; English, Loehr, Lee, & Smith, 2014; Gross et al., 2010). The eccentric phase is simply defined as the active lengthening of the muscle fibers (Jönhagen, Halvorsen, & Benoit, 2009). Based on the strength training principle, it is assumed that concentric and eccentric actions provide a different stimulus to the muscles and, thus, different adaptations may be produced (Roig et al., 2009). It has been well-documented in current research that skeletal muscle can produce more relative force during an eccentric muscular action than in other muscular actions (Muanjai et al., 2020; Pethick, Whiteaway, Winter, & Burnley, 2019). The strength of the eccentric muscles is essential to decelerate and stabilize the body during the braking phase of a jumping exercise or in tasks with a rapid change of direction (Chaabene, Prieske, Negra, & Granacher, 2018). Therefore, the authors of the current study propose that strength training with accentuated eccentric muscle actions is a promising element in strength and conditioning programs for sports with high-speed demands.

Several novel characteristics, including an augmented anabolic signal, are associated with supramaximal intensity or heavy load eccentric actions when compared with both concentric, or even lighter eccentric contractions (Douglas, Pearson, Ross, & McGuigan, 2017b, Buñuel, Cordero-Tencio, & Moncada-Jiménez, 2022). Also, neuromuscular changes result from chronic eccentric resistance training (Douglas et al., 2017a). However, the mechanism behind these changes remains unexplained. Lower metabolic cost per unit of external work and greater capacity to produce force is the individual response of eccentric training versus concentric and isokinetic action types (Suchomel et al., 2019).

According to Hortobaágyi (2000), eccentric exercise can lead to rapid strength gain and decreased cardiovascular stress in terms of heart rate, mean arterial pressure, rate pressure product, and perceived exertion (Flück, Bosshard, & Lungarella, 2017). Also, studies have shown that these exercises may improve power due to increased sarcomeres and fascicle length after eccentric exercises (Vogt & Hoppeler, 2014). Furthermore, maximal power can be increased by eccentric and interval exercises (Bhatia & Kayser, 2019; Elmer, Steven & Martin, 2010). However, one of the main questions is the effect of interval exercises, primarily aerobic, on power and strength. Eccentric exercises have some advantages over other contractions, and these effects are well-studied. However, concerning interval-type eccentric exercise - while some studies currently prove its advantages - more research must be carried out. The aim of this study was to determine the effect of interval and resistance training - with a focus on the eccentric phase - on the cardiovascular fitness and strength of elite handball players.

Materials and Methods

Participants

The present investigation is a randomized controlled experimental study. All subjects were healthy, physically active, and male Iranian elite handball players. A total of 30 elite handball players in the East Azerbaijan and Guilan provinces were recruited to take part in the study (table 1). The sample was randomly divided into two groups: a control group (CG; n=15; 21.40±1.76 years old) and a training group (TG; n=15; 20.93±1.70 years old). The inclusion criteria of this study included: 1. Seven hours of weekly training. 2. At least ten years' experience playing handball. 3. Playing at a national level in the last three years. Exclusion criteria included: 1. Presenting musculoskeletal or joint disorders/injury or disease in the previous month. 2. Not completing the designated training period. 3. The consumption of specific drugs. This study followed the ethical standards as outlined in the Declaration of Helsinki. The participants signed a form giving their informed consent for their participation in this study. This research has been approved by the Research and Ethical Committee of the University of Tabriz (Iran). The identification number of the study has been IR.TABRIZU.REC.1400.030, being approved on 09/26/2021.

Table 1.
Characteristics of the groups and analysis of homoscedasticity.

	Control Group n=15	Training Group n=15	Student t test
	Mean±SD	Mean±SD	t; Sig
Age (years	21.40±1.76	20.93±1.70	t=0.223; Sig:0.641
Height (cm)	176.87±4.43	178.26±3.86	t=0.077; Sig:0.783
Weight (Kg)	77.46±5.92	78.20±4.58	t=0.530; Sig:0.473
BMI (kg/m^2)	24.75±1.48	24.64±1.43	t=0.208; Sig:0.652

Leyend: BMI= Body mass index.

Assessment

A basic anthropometric assessment of weight (kg), height (m), and BMI were recorded. The anthropometric measurements followed the protocols of the ISAK (Ross & Marfell-Jones, 2013). First, height was measured using a stadiometer (Model HR001, Tanita Corp, Amsterdam, Netherlands) to the nearest 5mm. Next, weight was measured using a scale, Beurer (Model BF105, Germany), to the nearest 0.1kg. Finally, BMI was calculated by dividing weight (kg) by height (m) squared.

Muscle strength

This study used a 1RM seated chest press test to measure upper body strength. The 1RM was assessed as maximum resistance. In this movement, the subject has to lift this weight with the correct form throughout the full range of motion. For this assessment, the subject must select a weight that allows them to repeat as many movements as he can without exceeding 12 repetitions. 1RM can be obtained using the formula below: 1RM=Lifted weight / [1.0278 – (0.0278*repetition)] (Melo et al., 2008).

Cardiovascular Fitness

Cooper's 12-minute test was applied to assess the cardiovascular capacity of the handball players. The objective of this test is that the participant covers the greatest distance possible in 12 minutes. The test must be carried out by the participants running at the maximum possible speed. Studies show that Cooper's test correlates well with VO2 max (Hietapakka, 2012).

Muscle stamina

A push-up test was employed to measure upper-body muscle stamina. The 90° push-up required the participants to lie face down on the floor with their hands placed under their shoulders, fingers pointed forward, and elbows pointed back along the sides of the body. They then pushed

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up to full arm extension, so that the body weight was resting on the hands and toes; this was the up position. Then, keeping the body straight, the participants lowered theselves until the whole body from chest to thighs was touching the floor. The participant then pushed up to full arm extension and returned to the up position. This down and up cycle counted as one 90º push-up repetition. The participants then continued these steps at a comfortable pace, with no rest, until fatigued. One 90º push-up test was counted when the participant started at the up position, went to the down position, and returned again to the up position. The score was the number of 90º push-ups tests executed correctly before stopping, or when the required body position was changed (Hashim, Ariffin, Hashim, & Yusof, 2018).

Seated Medicine Ball Throw

The participants sat on the ground with their lower limbs extended and their backs, shoulders, and heads against a wall. They held a 3kg medicine ball in both hands with their upper limbs in abduction and elbows flexed. From this position, they were instructed to throw the medicine ball straight ahead as far as possible without their head, shoulders and back losing contact with the wall. Three attempts were made, with a two-minute rest between throws. The best of three attempts was recorded.

Training program

Before starting the training program, the participants familiarized themselves with the steps and the execution of the different movements included in the program (table 2). The intervention was performed during the preseason period. The training program took place over 12 weeks, with five sessions per week, consisting of two aerobic exercises, and three muscular resistance training exercises focused on the eccentric phase (with the tempo of 4 second). The aerobic training was carried out on a handball court. The strength work was performed in a gym. All players carried out assessments and training in the same facilities. The experimental group performed the intervention along with their regular handball training, while the control group only performed their regular handball training exercises.

In the aerobic training sessions of the first month, the athletes participated in two extensive running sessions per week, lasting between 35 and 50 minutes, with a heart rate of 50 to 60% of their max HR, depending on the position and level of the player. For the strength sessions, 16 strength exercises were undertaken; three sets with ten repetitions were performed, with a rest of between 90 and 120 seconds between sets. In the second and third months, the intensity of the exercises was increased in both the aerobic and bodybuilding sections. In the first aerobic training session, the athletes ran two sets of 20 minutes at 80-85% of their max heart rate and rested 6 minutes between the two sets. In the second aerobic exercise session, athletes performed four sets of 8 minutes, reaching ranges of 85% of max heart rate, with an active rest between each set of 3 minutes. To monitor the heart rate in subjects, a chest belt heart rate monitor (SUUNTO smart belt) was used.

For strength training, the first and third weight training sessions, at the beginning and end of the week, only consisted of three movements (Table 2). Each movement was repeated over 4 sets, with six repetitions in each set performed, focusing on the negative part of the movement over a period of 4 seconds. The weight was calculated as 65% of the maximum strength of the handball players, and the rest between each series was 2 to 3 minutes. The second weight training session, which was chosen to develop stamina, using only 50% of the athletes´ maximum strength, was chosen as general training for the whole body. Each movement was repeated over three sets; each one consisted of 20 to 30 repetitions with 60 seconds of rest between sets.

Table 2.
Strength training program.

First-month program training					Eccentric resistance training with the tempo of 4 second			
No	Exercise	Sets	Reps	Rest (second)	Exercise	Sets	Reps	Rest (second)
1	Squat	3	10	90-120	Squat	4	6	240
2	Leg Extensions	3	10	90-120	Barbell Bench Press	4	6	240
3	Lying leg curls	3	10	90-120	Barbell shoulder press	4	6	240
4	Standing machine calf raise	3	10	90-120	Squat	4	6	240
5	Barbell Bench Press	3	10	90-120	Resistance training focused on endurance			
6	Leverage incline chest press	3	10	90-120	Squat	3	20-30	60
7	Fly dumbbell	3	10	90-120	Leg Extensions	3	20-30	60
8	Barbell shoulder press	3	10	90-120	Lying leg curls	3	20-30	60
9	Behind the neck press	3	10	90-120	Barbell shoulder press	3	20-30	60
10	Dumbbell shoulder press	3	10	90-120	Behind the neck press	3	20-30	60
11	Side lateral raise	3	10	90-120	Barbell Bench Press	3	20-30	60
12	Front dumbbell raise	3	10	90-120	Leverage incline chest press	3	20-30	60
13	Seated cable row	3	10	90-120	Seated cable row	3	20-30	60
14	Standing barbell curl	3	10	90-120	Standing barbell curl	3	20-30	60
15	Standing dumbbell curl	3	10	90-120				
16	Triceps extension	3	10	90-120				

Statistical analysis

Descriptive statistics were used to obtain the metrics of central tendency, deviation, and percentages (mean, standard deviation, and percentages). The descriptive analysis was done by stratifying the sample according to the group (control and training). The Shapiro-Wilk test was used to test the normality of the data. The analysis of the intragroup training effect was verified through the paired sample t-test. To identify the differential effect of the programs undertaken by the control group and the training group, a 2x2 multivariate analysis (MANOVA 2X2) was applied. All statistical analyzes were performed using SPSS version 25 (SPSS Inc., Chicago, IL, USA). The p-value was set at <0.05.

Results

Descriptive statistics of anthropometric characteristics of the male handball players from each of the two groups are shown in Table 1. Both groups are homogeneous samples, where no differences between TG and CG have been recorded. Of the conditional variables evaluated, the initial values did not show significant intergroup differences for any of the dependent variables.

All data for both groups increased after the 12-week intervention (Figure 1), but only significant differences were recorded for TG. The results in both groups improved between the pre and post-test, but significant differences were only registered in the experimental group. Except in the cardiovascular endurance test, in the pretest, the best results are recorded by the control group.

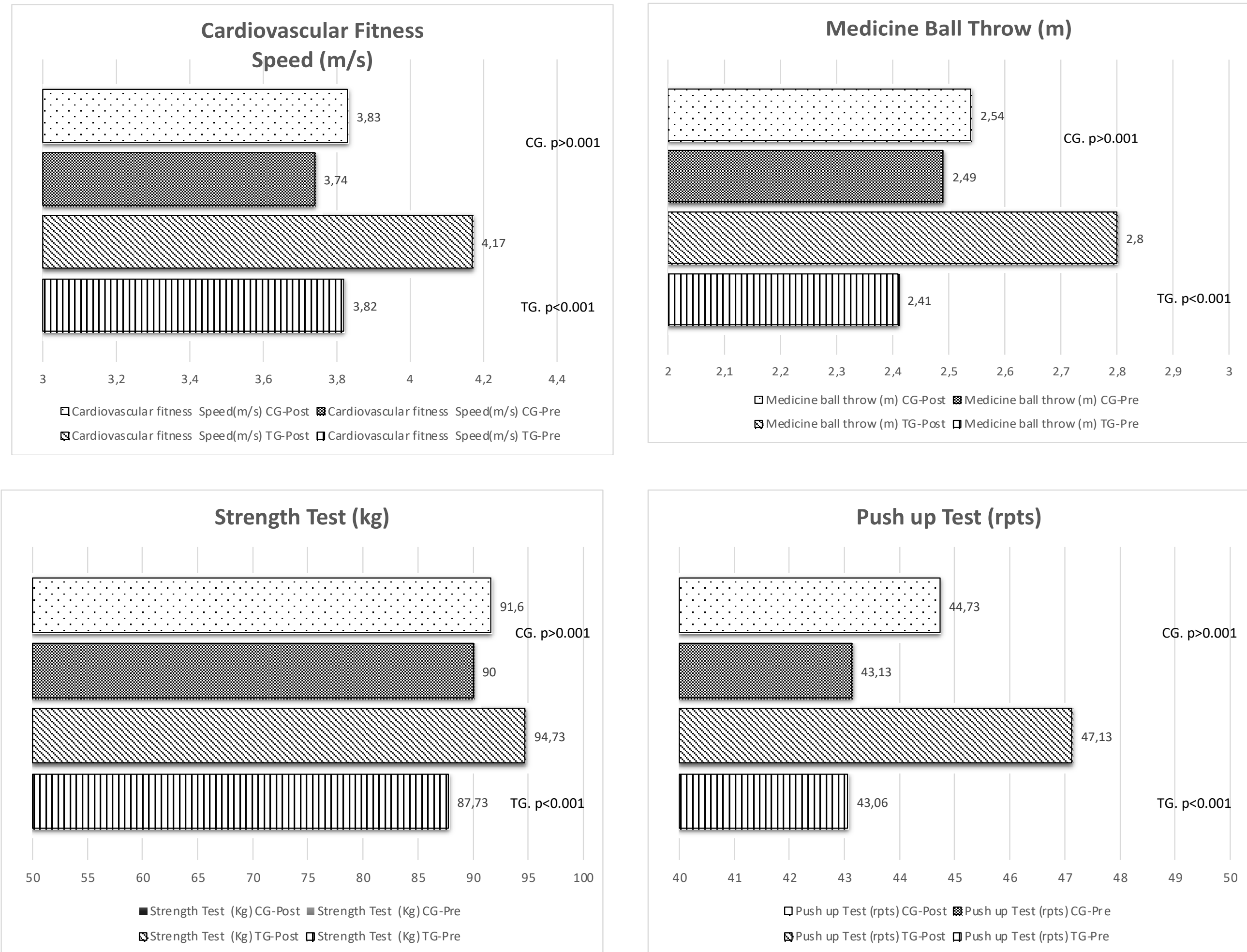

Figure 1. Performance in Training Group (TG) and Control Group (CG) before and after the 12-week intervention in male handball players.

With a significant interaction of group and intervention, the TG showed an improvement in all the strength and resistance variables evaluated (Table 3) of the TG.

Table 3.
MANOVA 2X2 test (Univariate test).

Variables		Sum of squares	Df	Mean square	F	Sig
Cardiovascular fitness	Contrast	303976.87	1	303976.87	13.29	<0.001
	Error	617123.47	27	22856.42		
Muscle strength	Contrast	176.92	1	176.92	11.74	<0.002
	Error	406.68	27	15.06		
Push up Test	Contrast	45.23	1	45.23	6.10	<0.020
	Error	199.94	27	7.40		
Medicine ball throw	Contrast	0.78	1	0.78	22.10	<0.001
	Error	0.95	27	0.035		

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Discussion

This study examined the effects of a 12-week preseason eccentric resistance training program on components of physical performance in male handball players. The main findings showed that eccentric resistance training was effective in improving the metrics in cardiovascular fitness, muscle strength, the Push up test and the medicine ball throw test.

The ability of handball players to produce explosive efforts (running, jumping, changing direction, throwing) is essential for the success of individual technical-tactical actions. The findings of the present study showed gains in the performance of all the variables analyzed for the TG, which should mean an improvement in the individual actions (more explosive) of the handball players, and also their aerobic power. The training program of the present study was eccentric resistance training; according to some studies, this type of contraction induces more significant improvements in the stretch-shortening cycle, (Elmer, Steven et al., 2012), strength (English et al., 2014), and power (Walker et al., 2016), when compared with traditional resistance training. Most handball movements are concentric (throwing, shooting, explosive movements). As shown in Table 4, the results indicate that the improvements result from the design of the training program. However, to continue strength improvement in highly trained handball players, they may need a different stimulus to enhance their performance, and eccentric training has produced more significant strength gains in this group.

Sabido et al. (2017) reported that strength and athletic performance could be improved by adding a single eccentric-overload training session per week during a 7-week training program consisting of four sets of eight repetitions. In their study, the participants′ strength was improved in both the concentric and eccentric phase. In contrast, Chaabene et al. (2020) stated that replacing the Nordic hamstring exercise (a form of eccentric exercise) with some traditional exercises can significantly improve the performance of handball players. The training program considered here, however, has proved to be more effective than traditional training. This study's results align with those presented by Sabido et al. (2017) and Chaabene et al. (2020), where the results indicate that the improvements are the result of the intervention itself.

Based on previous studies, the architectural measurements of muscle size and physiological cross-sectional area (PCSA) are associated with muscle strength (Albracht, Arampatzis, & Baltzopoulos, 2008). Potier et al. (2009) experimented with eight weeks of eccentric training of the biceps femoris. According to their study, eccentric-based exercises could increase fascicle length by 34% without any changes in pinnation angle. Theoretically, a significant increase in fascicle length with eccentric training could extend the inter-aponeurosis distance and length of the whole muscle (Potier, Alexander, & Seynnes, 2009, Martins, Cardoso, Honório, & Silva, 2020). One of the variables that can lead to architectural changes in muscles is the duration of the eccentric program training. The duration of these training programs can range from as few as five weeks to as many as 52 weeks. Seynnes et al. (2007) showed that a significant increase in fascicle length occurs after five weeks, but that before this time, there is no significant change. Undoubtedly, muscle force production and muscle size are strongly affected by fascicle arrangement (muscle architecture) within the muscle (Alegre, Jiménez, Gonzalo-Orden, Martín-Acero, & Aguado, 2006). The training program in the present study is more than five weeks long (12 weeks), so it can thus definitely affect the architecture of muscles and increase Strength. According to the results of the present study, the training program undertaken here can improve Strength in handball players.

However, the regular exercises undertaken by both the groups, which also lasted 12 weeks, may have increased Strength significantly too. This result may be because of the elite, professional level of the players, and the fact that, at this level, making significant changes is a challenge. Furthermore, the experimental training group performed the eccentric exercises alongside their regular exercises. Another factor influencing the results is the fact that the ratio between different types of muscle fibers is determined mostly genetically (Ahmetov, Vinogradova, & Williams, 2012; Simoneau & Bouchard, 1995). Since power is the combination of Strength and time, Strength has to increase to influence explosive power. Accordingly, greater gains in explosive power are due to increased muscle strength. Therefore, there is a positive linear relationship between Strength and power (Marsh et al., 2006; Post, Dawes, & Lockie, 2022).

One of the main limitations of the study was not being able to perform an intervention during the season, to assess a minimal recommended training dose and to identify the minimum number of exercises and their repetitions needed to maintain the improvements achieved during the preseason. On the other hand, studies frequently show that eccentric exercises increase strength more than other muscle actions. Some studies reported that strength gains from eccentric exercise tend to be more speed specific when incorporating testing and training speed (Roig et al., 2009). Therefore, the incorporation of execution speed in the eccentric phase seems essential.

Conclusion

We can conclude that an eccentric-based program can improve muscle strength and stamina, Power, and cardiovascular fitness. It is necessary to highlight the usefulness of this low volume/high intensity training in the optimization of dynamic sports performance in handball players.

Practical application

The performance improvements shown in the present study are of great interest to handball coaches because handball performance is highly dependent on the specific skills of power, jumping, sprinting, and throwing that were improved with the high endurance training regime. This study shows that elite male handball players who are considered well-trained can improve strength and aerobic power by performing a 12-week program during the preseason that includes exercises for both upper and lower limbs. It should be kept in mind that the members of the sample are professional players who are accustomed to training - and even so a month of adaptation and preparation for eccentric training was performed - so therefore it is not recommended for players unaccustomed to training professionally.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the paper.

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