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ORIGINAL

THE EFFECT OF STRENGTH TRAINING ON THROWING VELOCITY IN TEAM HANDBALL

EFFECTO DEL ENTRENAMIENTO DE LA POTENCIA SOBRE LA VELOCIDAD DE LANZAMIENTO

Aguilar-Martínez, D.¹; Chiroso, L.J.²; Martín, I.³; Chiroso, I.J.⁴ & Cuadrado-Reyes, J.⁵

¹Diplomado en Estudios Avanzados CCAFD por la Universidad de Granada, España, daguim@correo.ugr.es

²Doctor CCAFD por la Universidad de Granada, Profesor Titular Departamento de Educación Física, Universidad de Granada, España, ichiroso@ugr.es

³Doctor en Psicología Social y Metodología de las Ciencias del Comportamiento por la Universidad de Granada, Profesor Titular Departamento de Metodología de las Ciencias del Comportamiento, Universidad de Granada, España, imartin@ugr.es

⁴Doctor CCAFD por la Universidad de Granada, Profesor Asociado Departamento de Educación Física, Universidad de Granada, España, ichiroso@ugr.es

⁵Doctor CCAFD por la Universidad de Granada, España, jorgecu@correo.ugr.es

Spanish-English translator: Lindley McCarthy. E-mail: lindleymac@gmail.com

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ABSTRACT

The purpose of this study was to examine the effect of different strength methods combined with technical-tactical training on muscle power and throwing velocity in both arms of team handball players. Eleven senior players participated (25 ± 3 years; $188,7 \pm 4,7$ cm; $90,6 \pm 10$ Kg) in this study. The season was divided into three training periods, each of eight week, to test different methods of strength training. The results show that strength training based on the contrast static - dynamic combined with technical- tactical training during the

competitive season is more effective ($p=0.033$) that only the realization of maximum strength training combined with peak power for improving throwing velocity.

KEY WORDS: Team handball, complex training, throwing velocity, strength training

RESUMEN

El propósito de este estudio fue examinar el efecto de diferentes métodos de fuerza unidos al entrenamiento técnico – táctico sobre la potencia muscular y la velocidad de lanzamiento en ambos brazos. Los participantes fueron 11 jugadores senior de balonmano (25 ± 3 años; $188,7\pm 4,7$ cm; $90,6 \pm 10$ Kg). Se tomaron 3 periodos de entrenamiento, cada uno de 8 semanas, con diferentes métodos de entrenamiento de la fuerza. Los resultados muestran como el entrenamiento de fuerza basado en el contraste estado – dinámico unido al entrenamiento técnico – táctico durante el periodo competitivo es más eficaz ($p=0,033$) que sólo la realización de entrenamiento de fuerza máxima combinada con el pico de potencia para la mejora de la velocidad de lanzamiento.

PALABRAS CLAVE: Balonmano, entrenamiento integrado, velocidad de lanzamiento, entrenamiento de la fuerza

1 INTRODUCTION

Team handball is a 7 vs. 7 game played on a 20x40m court in two periods of 30 minutes each. There are total of 14 players on each team, and each team is allowed unlimited substitutions. Limitless substitutions keep match intensity at a very high level. The nature of the game means intermittent efforts mostly use phosphagen systems in decisive actions. A handball player must demonstrate a high level of explosive strength (in different expressions of force). Simultaneously, players must have high oxidative phosphorylation resilience in low intensity periods enabling quick recovery. The game includes numerous repetitive actions like full speed running, changes in speed and direction, jumping, throwing, and collisions between players (Marques, Van Den Tillaar, Vescovi and González-Badillo, 2007).

One of the single most important technical-tactical elements, the intrinsic purpose of a competitive game and the key to winning the game, is shots on goal (Anton, 1998). The effectiveness of these shots depends on the success of the preceding actions and affects possible victory. It is well known that a successful shot on goal in handball depends on throwing ability and ball velocity (Gorostiaga, Granados, Ibanez and Izquierdo, 2005; Granados, Izquierdo, Ibañez, Ruesta and Gorostiaga, 2008; Marques et al., 2007; Skoufas et al., 2003; Skoufas et al., 2008). Although previous studies have demonstrated that velocity can impair accuracy, in elite players this inverse relationship is not significant (Párraga, Sanchez and Oña, 2001).

There are three determining factors critical to regulating the speed of ball release: a) those related to the mechanics of the throw; b) related coordination processes (intra- and intermuscular); and c) those related to force development and/or power in the upper and lower extremities (Marques et al., 2007).

Throwing Mechanics

The mechanics of handball throws have been widely studied from different perspectives (Granados et al., 2008; Rivilla, Sampedro, Gomez-Navarro and Ortiz, 2010; Sachlikidis and Salter, 2007; Skoufas et al., 2003; Skoufas et al., 2008; Van Den Tillaar and Ettema, 2006; Van Den Tillaar and Ettema, 2007; Zapartidis, Gouvali, Bayios and Boudolos, 2007). When analysing these mechanics, it is important to differentiate between types of throws (for example, overarm throws, standing throws and a three step running throw), taking into account the opposition and ball release location (Bayer, 1987; Párraga, 1999; Rivilla et al., 2010). There are differences in mechanical performance based on whether or not subjects are experts or novices (Skoufas et al., 2003; Skoufas et al., 2008; Van Den Tillaar and Ettema, 2006), and whether or not the ball is thrown with the dominant or non-dominant arm (Ettema, Gløsen and Van den Tillaar, 2008; Gray, Watts, Debicki and Hore, 2006; Hore, O'Brien and Watts,

2005; Sachlikidis and Salter, 2007; Skoufas et al., 2008; Van den Tillaar and Ettema, 2006; Van den Tillaar and Ettema, 2009;).

In ball throwing mechanics, improvements in shoulder rotation occur in both the dominant and non-dominant arm, but there is no relation between the release rates in each arm (Newsham, Keith, Saunders and Goffinett, 1998). These velocities are very different if the release arm has undergone technical-tactical training and therefore develops a higher quantitative yield. Different studies demonstrate that there are biomechanical differences in throws made with the dominant and non-dominant arm. Throws made with the non-dominant arm have lower angular velocities at different points, making the final speed is lower with respect to the dominant arm (Gray et al., 2006; Hore et al., 2005; Newsham et al., 1998; Sachlikidis and Salter, 2007; Van DenTillaar and Ettema, 2009). An athlete's lateral dominance, (or handedness) also influences the accuracy of the throw (Aragón, Fernández-Santos, Gomez-Espinosa, Carrasco, Mora, and González Montesinos, 2010).

Coordination processes

Throwing differences between arms may occur because the non-dominant arm usually hasn't developed the same coordination mechanisms to effectively exploit moments of interaction in different phases of the kinetic chain (Gray et al., 2006). However, there is a relationship between dominant and non-dominant coordination at ball release, therefore if a player learns to throw ambidextrously, he or she can more easily increase throwing velocity in both arms due to bilateral transfer phenomena (Sachlikidis and Salter, 2007).

There are technical differences between each arm with respect to coordination, but this does not mean that throwing stability is sacrificed (Van den Tillaar and Ettema, 2006). Arguably, technical differences are due to the existence of different movement patterns (Hore et al., 2005; Van den Tillaar and Ettema, 2009). Obviously, the movement pattern of the dominant arm is more effective and more consolidated in expert players. One of the reasons that non-expert subjects cannot throw faster with their dominant arm is because they have not developed the coordination mechanisms to exploit the so-called moments of interaction in different phases of the kinetic chain (Van den Tillaar and Ettema, 2006; Wagner and Mueller, 2008).

Muscle strength and power development

Ball release velocity depends in part on the ability of each player to generate maximum dynamic force (MDF). The higher the level of the player, the higher absolute values of MDF and throwing velocity (Gorostiaga et al., 2005; Granados et al., 2008), although there is no direct relationship between these two expressions of force.

As teams seek the best possible athletic performance, a significant portion of training is dedicated to improving different expressions of force to achieve optimum performance in specific game skills. The use of any load while trying to attain maximum performance has a positive effect on force development (Chirosa, 1998). However, the most important factor in the training process is knowing how to adjust training loads in order to achieve peak performance at any given time during the competitive season.

Applied force, good mechanical release, and most importantly, explosive force in both the lower and upper extremities, all influence throwing velocity in handball players (Chelly, Hermassi and Shephard, 2010). In some studies, explosive force is linked to throwing velocity (Skoufas et al., 2003) indicating that if lighter balls are used, shoulder rotation speed increases and therefore ball throwing velocity increases. In highly trained players, strength training can be mixed with technical-tactical training to increase throwing velocity (Skoufas et al., 2003).

As in previous, relevant studies, it is important to study the development of appropriate methods to increase force in order to increase players' ball throwing velocity (Chelly et al., 2010; Dalziel, Neal and Watts, 2002; Ettema et al. 2008, Skoufas et al., 2003). However, few studies examine the relationship between the development of throwing velocity in elite handball players with indices of strength and power dynamics (Marques et al., 2007).

To our knowledge, there are no studies on the application of different methods of strength training during a competitive season to increase or maintain the parameters of peak power and throwing velocity in both arms in team handball. Therefore, the purpose of this study was to examine the effect of different methods of strength training combined with technical-tactical training on upper extremity muscle power and throwing velocity in both the dominant and non-dominant arms in handball players at different times during the competitive season. The objective was to determine the effect of different methods of strength training on throwing velocity.

To carry out this study, different methods of strength training, based on previous research (Gamble, 2006; Marques and Gonzalez-Badillo, 2006; Marques et al., 2007; Skoufas et al., 2003; Van den Tillaar, 2004) including: maximum power; peak power; complex training; and integrated training (Chirosa, 1998; Ingle, Sleaf and Tolfrey; 2006; Santos and Janeira, 2008) were used to provoke changes in ball throwing velocity in both arms.

METHOD

2.1 SUBJECTS

Eleven players from a national senior handball team participated in this study. The average age was 25 ± 3 years, and all players had an average of 16 ± 3

years experience in the sport. The key anthropometric data of the team were: height (188.7 ± 4.7 cm), weight (90.6 ± 10 kg) and fat mass ($11.5\% \pm 2.8$ kg).

Players did not take exogenous anabolic-androgenic steroids or other banned substances or drugs that could affect performance or hormonal balance during this study. Several players underwent doping controls administered by the Spanish Federation of Handball during the study and there were no infringements. No medications that could alter the results of the study were taken at the time during the study.

2.2 DESIGN AND VARIABLES

The variables in the following study include:

Dependent variables (DV) were each player's throwing velocity (ThV) and the peak power in the bench press (PP).

The training method was the key independent variable (VI_1) to study its effect on the dependent variables. There were three variations in the training method, each corresponding to an eight-week session. The first variation (M1), was a general strength training program; (M2) was strength training combined with technical-tactical training and (M3) was combined specific strength and technical-tactical training during the last third of the season. Data collection began when players reached the throwing velocity reached in previous seasons to negate the influence of any post-training period (Marques and González-Badillo, 2006).

Other independent variables in the study were measured before and after each combined training method (VI_2 : Pre and post) and each arm (VI_3 : dominant arm and non-dominant arm).

Therefore, this is a quasi-experimental design with repeated measures. When ThV was measured each of the three independent variables were manipulated, whereas when the DV was PP, there were only two independent variables: pre- and post methods. The order of the training methods could not be counterbalanced since the design had to be adapted to the context of a real team in real competition and, therefore, has great ecological value despite losing some form of internal control in the investigation. In any case, the non-dominant arm was measured and served as a control to measure the improvement of the dominant arm.

2.3 MATERIAL

The equipment used to conduct this research included: a radar gun with a range of 10 to 199 km / h, $\pm 2/3$ km / h, a linear rotary encoder (1mm 1000Hz frequency accuracy and registration), and Real Power software, HP nx7400 notebook and SPSS15.

2.4 PROCEDURE

Participants trained with the same coach on the same team in the two years prior to the study, as well as during the study period. Before participating in the study, all players underwent a thorough medical examination, including an electrocardiogram stress test. Subjects and coaches were informed of the purpose of the study and signed an informed consent to participate in it.

All tests were carried out during the competitive season. Players were familiar with the experimental tests, as they had participated in the same tests in other seasons. The evaluation procedure was always standardized and began after two days of postgame recovery, with the same test protocol. Subjects participated in the tests in random order. Subjects who experienced physical problems and did not participate in all tests, were excluded from the study.

Strength training methods were controlled to determine their effect on throwing velocity and upper extremity muscle power at three different times in the season. Tests were conducted during the first eight-week session, which did not include technical-tactical training (M1), during the second 8-week session (M2), and during the third and final eight weeks of the season (M3). Throwing velocity in specific actions using both the dominant and non-dominant arms were controlled. Other factors were also controlled including the volume and intensity of throws and evolution of the force-velocity curve, mainly analysing maximum power.

Throwing Velocity Test

Maximum ball velocity after throws were measured using a radar gun (with a range of 10 to 199 km / h, ± 2.3 km / h) performing a three step run, and then shooting the ball to the middle of the goal at a distance of 9m frontal radar position, as used in previous research (Marques et al., 2007; Van den Tillaar and Ettema, 2006; Van den Tillaar and Ettema, 2009). The radar was located in a fixed position behind the goal and adjusted to the shoulder height of the player. An official IHF (International Handball Federation) ball weighing 475 g and measuring 58 cm in diameter was used in this test. After a 10 minute standardized warm-up, players began to throw at full velocity using both their dominant and non-dominant arms, and their preferred throwing technique/stance. There were three sets of three throws with three minutes rest between series and between throws. The best throw was used for subsequent analysis. Coaches supervised throws throughout the test to ensure that subjects were using proper technique.

Force-Velocity Curve

Measurements were made using a rotary linear encoder, which works with a dynamo system, detecting and reporting the position of the bar every 10

milliseconds (1000 Hz) to an interface connected to a laptop using Real Power software to automatically calculate values of force, velocity and peak and average power and to record a 1mm minimum change in position. The end of the cable end was secured to a specific location on the bar so as not to interfere with the exercise. When a subject is exercising, the cable travels vertically in the direction of movement.

All participants used an initial weight of 26 kg (Marques et al., 2007), which was subsequently increased by 5 or 10 in each trial until the athlete reached maximum power, demonstrated and recorded the help of software. The test began with the help of two trainers. The bar was placed on the athlete's chest 5 cm near the jugular notch and the athlete was forced to keep it there for about 1 second before starting the movement in order to minimize the counter movement effect on the results. Two hands spacing on the bar was controlled at 120% of the biacromial diameter. Then the player was instructed to perform a concentric action from this position, as quickly as possible, until the elbows were fully extended. There were 3 to 5 minutes rest between trials to reduce the likelihood of fatigue. A trial was annulled if it appeared that there was a counter movement of the bar at the start of the test, if the athlete lowered their back or raised their buttocks from the bench, or if the athlete was unable to extend his elbows.

Technical – Tactical Training

Planning was been designed according to the principles of training (Buford, Rossi, Smith and Warren, 2007; Kelly and Coutts, 2007), using a periodization model applied to longterm competitive sports.

2 RESULTS

3.1 Throwing Velocity

Using the results, an intra-subject ANOVA was performed with three independent variables. For this analysis, sphericity was assumed since there were no differences in the Mauchly test. The results show significance in the dominant – non-dominant variable ($F_{1,10} = 209.660$, $p = 0.0001$; $E^2 = 0.954$, power = 1.00) and with the interaction of time with the dominant-non-dominant variable ($F_{2,20} = 7.360$, $P = 0.004$, $E^2 = 0.424$, power = ,899) (Figure 1).

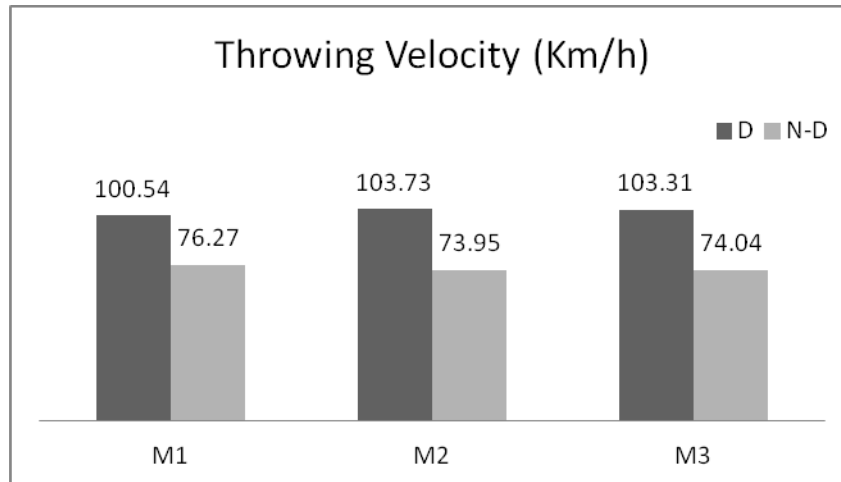


Figure 1. Throwing velocity as a function of dominant and non-dominant arm and the time of study

The average throwing speed in the dominant arm was 102.53 km/h while the in non-dominant arm it was 74.76 km/h. However, the Bonferroni comparisons of interaction time to dominant-nondominant arm showed significant differences among the means of the dominant arm compared to the non-dominant ($p < 0.001$) and for the dominant arm between stages 1 and 2 ($p = 0.033$) with no significant difference between stages 1 and 3 ($p = 0.067$).

3.2 Maximum Power

A repeated measures ANOVA was also used to analyse the dependent variable maximum power using two independent variables: pre and post-season. The Mauchly sphericity test was significant for the variable season ($W2 = 0.345$, $P = 0.008$) but not for the interaction between the variables ($W2 = 0.930$, $P = 0.721$). Therefore the Greenhouse-Geisser test was chosen in the first case.

The results are significant only for the variable "moment" ($F1.208$, $12.082 = 5.870$, $p = 0.027$). Analysis of the comparisons between each of the three measures using the Bonferroni test show differences between 1 and 3 ($p = 0.007$) and between 2 and 3 ($p = 0.027$) (Figure 2).

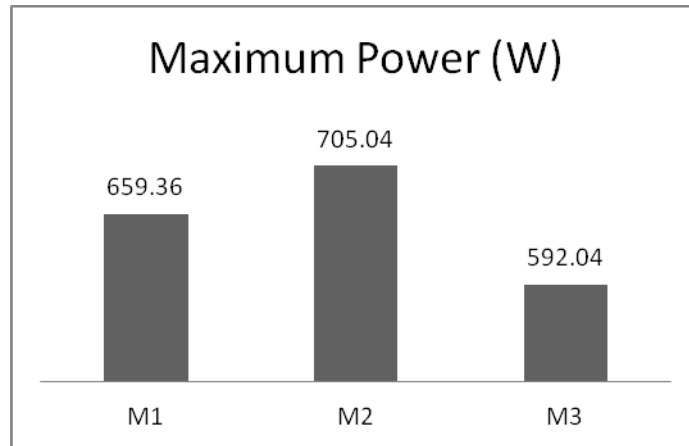


Figure 2. Maximum Power at the time of the study.

3 DISCUSSION

The purpose of this study was to examine the effect of different methods of strength training combined with technical - tactical training on upper extremity muscle power and throwing velocity in handball players. The major contribution of this paper is demonstrating that strength training based on stable–dynamic contrast in repeated loads of 100% of maximum power combined with technical - tactical training at a given time in the competitive season is more effective ($p = 0.033$) than only maximal strength training combined with maximum power to improve throwing velocity. It should be noted that the application of strength training based on the maximum power and the technical - tactical training combination, is justified based on the evidence that a standard training regimen consisting of pulley movements does not improve throwing velocity in expert players (6.1% vs 1.4%, $P = 0.085$) (Ettema et al., 2008). Dalziel et al. (2002) combine power exercises at 30% of 1RM with specific training in handball for increasing levels of maximum power and throwing velocity. In this experiment, the player’s maximum power levels were kept between 20-40%, concurring with the Dalziel study.

The data suggests that these methods of strength training must be accompanied by specific tactical - technical exercises in order to develop one of the most necessary game skills: the shot on goal. However, not all combinations of strength and technical - tactical training produce the same effects. A method based on 120% of maximum power used at the end of a season does not reach significant values ($p = 0.067$). A detailed analysis of the increases that occurred highlights a 2.3% decline in throwing velocity in (M1), or the application of only force between pre and post. It shows increased throwing velocity at other times (M2 and M3) of 1.4% and 1.9%, respectively between pre and post. According to Gorostiaga et al. (2006), this increase is due to the efficacy of the combination of strength and technical - tactical training when many explosive, release actions occur. The increases in this study are lower than those achieved by (Gorostiaga et al., 2006; Granados et al., 2008; Marques and Gonzalez-Badillo, 2006) who attained improvements of about 7%. However, Gorostiaga et al. (2006), Granados et al. (2008), and Gonzalez-

Badillo Marques (2006) also indicate that an increase in explosive actions, such as throws in trained athletes with high level of technical execution and high start values, in principle, makes improvements more difficult because athletes are already performing very close to their upper limits. In this study, the increases achieved in both throwing velocity and maximum power (3%) did not show significant differences between pre and post measures. However as the aforementioned authors state, it would have been difficult to record significant improvements since data collection began when the athletes had reached the throwing velocity and maximum power levels of previous seasons.

Similarly, Gorostiaga et al. (2006) and Marques et al. (2007) found no association between throwing velocity using 3 steps and maximum dynamic force (1RM) after endurance training in elite handball players. In this research, maximum dynamic force levels were used to check their influence on power and throwing velocity that handball players develop at given moments during a season. Throwing velocity in the non-dominant arm increased by 1.1% and maximum power increased by 3.2%. Neither increase is significant, so it is difficult to compare data from these studies.

It is necessary to consider the fluctuations of ball throwing velocity in top players at different times in the season (Gorostiaga et al., 2005; Gorostiaga et al., 2006; Granados et al., 2008; Marques and Gonzalez-Badillo, 2006) because it appears that timing in the season peaks influences this variable. This may indicate significance between throwing velocity and maximum power relative to a specific point in the season. Players have greater differences in throwing velocity between M1 and M2 ($p = 0.033$) so, as noted, when players reach their maximum throwing velocity, they have greater difficulty increasing this speed. There are significant differences in maximum power between M1 and M3 ($p = 0.007$) related to the method of strength training method used (F1). Again, the results are significant between M2 and M3 ($p = 0.027$) when strength training is combined with technical-tactical preparation there by increasing the number of tactical, explosive actions that players perform.

As Van den Tillaar and Ettema, (2009) indicate, in many team sports such as baseball, cricket and handball, throwing velocity is the most important variable in the game. In these sports, generally, only the dominant arm is used to throw the ball. The dominant and non-dominant arms differ in movements that are performed after the acceleration phase of the ball. Highly significant average results ($p = 0.0001$) were found in the differences in throwing velocity between arms. This data was obtained through a comparison of release rates from the dominant arm compared to the non-dominant. A priori, this seems logical as due to the differences in the throwing pattern in each arm. Slower throwing velocity in the non-dominant arm may be due to player's inexperience in taking shots with that arm, because it is a strange movement (Van den Tillaar and Ettema, 2009). Therefore, since overhead throwing is one of the most critical skills in handball, players must practice throwing with the non-dominant arm to try to acquire the same patterns of movement efficiency. Similarly, throwing differences between arms is not due to different experience or training. Rather, it

is the result of a decrease in angular velocities in the kinetic chain at different points leading to different throwing velocities between both arms. As players specialize, the differences between the two arms are increased since the use of non-dominant arm is gradually reduced in the training process.

At this point, it becomes important the existence of the exclusive strength training or strength training combined with technical – tactical training is even more important in order to reduce the differences between throwing velocity in both arms. The movement patterns of the dominant arm must be taught to the non-dominant arm to attain better results when shooting on goal. Therefore, combine technical- tactical training can help assimilate movement patterns of dominant and non-dominant arm.

It is worth noting that the design of this study ensures external validity since it is organic and easy to apply, but it poses problems for internal validity unless the participants are randomly chosen, and the study is counter balanced and the variable dominant and non-dominant arm can be exhaustively controlled. For example, in training it was impossible to control if the players used their non-dominant arm to perform specific actions at a given moment without inhibiting the research process since the study was conducted with players in a national league team during the competitive season. Therefore, it was more important to compare the results between one arm and the other, with the certainty that the non-dominant arm is hardly used versus other designs that could compromise the validity of studying players in their natural habitat.

4 CONCLUSIONS

- The combination of technical-tactical and strength training based on the static - dynamic contrast parameters increases throwing velocity and maximum power.
- There are differences in throwing velocity rate corresponding to different times in the season so as players reach maximum throwing velocity, it is difficult to achieve significant increases.
- Increased throwing velocity is achieved when combining technical - tactical training and explosive demonstrations of force and lead to greater improvements in various neuromuscular factors than when using the same training methods independently of each other.

Finally, the results indicate that significant differences between throwing velocity and maximum power are possible, so the sample should be expanded in order to verify these indications. This opens new avenues to study variables related to player training and learning from a functional point of view. For example, subsequent studies should focus on training based on the use of the dominant arm combined with training based on the use of

non-dominant arm to determine which creates improved motor skills and leads to better development of this fundamental handball skill.

PRACTICAL APPLICATIONS

- As player specialization increases, generally use of the non-dominant arm decreases. As previously noted, this leads to very significant differences in average release rates between the dominant and non-dominant arm. This suggests that athletes must learn to be ambidextrous during the initiation and consolidation process of learning and promoting ambidextrous players must be one of the objectives coaches to expand motor skills and increase the chances of success.

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