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CORRELATION BETWEEN INTERNAL SHOULDER ROTATION STRENGTH AND THROWING VELOCITY IN HANDBALL

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ABSTRACT

This study aims to check if there is a correlation between the internal shoulder rotation (ISR) strength of the dominant arm's without previous countermovement action, measured in an isotonic way by a new device (Dynasystem), with the throwing velocity in handball support. A transversal study of repeated measurements was carried out with twenty handball players from the First National category of Spain. Participants were instructed to perform 8 support throws from the 7-meter line of the handball court at maximum velocity, in goal, to calculate the mean and maximum throwing velocity. A 3 to 5 kilogram incremental test was performed, with 3' to 5' rests, to calculate the ISR repetition maximun of the dominant arm's without previous countermovement. Once the mean and peak velocity at which load of each relative intensity has been moved, has been measured, an individual force-velocity profile has been obtained for each player. There is no correlation between the ISR strength without countermovement of the dominant arm's shoulder, measured in an isotonic way, with the velocity of the ball in the standing handball throw without run.

RESUMEN

Este estudio tiene como objetivo comprobar si existe una correlación entre la fuerza de rotación interna del hombro (ISR) del brazo dominante sin acción previa de contramovimiento, medida de forma isotónica por un nuevo dispositivo (Dynasystem), con la velocidad de lanzamiento en apoyo de balonmano. Se realizó un estudio transversal de medidas repetidas con veinte jugadores de balonmano de la categoría Primera Nacional de España. Se instruyó a los participantes para que realizaran 8 lanzamientos en apoyo desde la línea de 7 metros de la pista de balonmano a máxima velocidad, a gol, para calcular la media y la máxima velocidad de lanzamiento. Se realizó una prueba incremental de 3-5 kilogramos, con descansos de 3' a 5', para calcular la repetición máxima de rotación interna del hombro del brazo dominante sin contramovimiento previo. Una vez que se ha medido la velocidad media y máxima a la que se ha movido la carga de cada intensidad relativa, se ha obtenido un perfil de fuerza-velocidad individual para cada jugador. No hay correlación entre la fuerza de rotación interna sin contramovimiento del hombro del brazo dominante, medida de forma isotónica, con la velocidad del balón en el lanzamiento en apoyo de balonmano sin carrera.

1. INTRODUCTION

Handball is an Olympic sport played all over the world, with nearly 18 million players in more than 150 international federations. From a physical point of view, handball is a contact sport, intermittent and vigorous, requiring high-intensity effort in a short period of time (Raeder, Fernandez-Fernandez, & Ferrauti, 2015). Studies on top-level handball players have shown that key characteristics for professional success include good cardiorespiratory endurance, jumping ability, sprinting speed, and high throwing velocity (Fieseler et al., 2017). Chelly, Hermassi, Aouadi, & Shephard (2014) state that, due to the intermittent nature of handball, being able to perform explosive muscle contractions is the most critical physiological characteristic for achieving greater performance in sprinting, jumping, changing direction and throwing the ball. Therefore, it has been demonstrated that muscle strength and power are the most important factors that give a clear advantage in elite competition, in addition to technical and tactical skills (Veliz, Requena, Suarez-Arrones, Newton, & De Villarreal, 2014).

According to various authors such as Cherif, Chtourou, Souissi, Aouidet & Chamari (2016) y Veliz et al. (2014), to achieve success in handball, it is essential to throw at goal. However, the overhead throw is a very complex gesture, with different joints and body segments contributing to its execution (Fieseler et al., 2017).

The shoulder joint, which acts as part of the kinetic chain involved in the transfer of energy from the lower extremities to the ball, plays a central role in the throwing mechanism (Skejø, Møller, Bencke, & Sørensen, 2019). Van den Tillaar et al. (2012) found that the angular velocity of the internal shoulder rotation when the ball is released and the maximum elbow extension contributes greatly to the ball's throwing velocity. They suggested that 67% of the ball throwing velocity was explained by the sum speed effect of elbow extension and ISR. The coordinated action of the shoulder muscles is vital for efficient performance and reduced risk of injury (Andrade et al., 2013; Mascarin et al., 2017). In the throwing gesture, the ISR movement plays an important role in accelerating the upper extremity (Debanne & Laffaye, 2011; Van Den Tillaar & Ettema, 2007), specifically in the assembly phase, as the internal rotators of the shoulder benefit from the stretch-shortening cycle, directly affecting the throwing velocity in the acceleration phase (Sarvestan, Riedel, Gonosová, Linduška, & Přidalová, 2019) which leads to a high-speed movement before the ball throw.

Numerous studies have shown a positive correlation between the strength and power that players were able to develop in general in different exercises (press bench, pull over, medicine ball throwing, half squat) with the velocity of the ball during throwing (Marques, van den Tilaar, Vescovi, & Gonzalez-Badillo, 2007; Hermassi, van den Tillaar, Khalifa, Chelly, & Chamari, 2015; Chelly, Hermassi, & Shephard, 2010; Cherif et al., 2016; Aguilar-Martínez, Chirosa, Martín, Chirosa, & Cuadrado-Reyes, 2012; Hermassi, Chelly, Fathloun, & Shephard, 2010). In this line, the study conducted by Ortega-Becerra, Pareja-Blanco, Jiménez-Reyes, Cuadrado-Peñafiel, & González-Badillo (2018) found significant associations between absolute load lifted at 1m/s in the bench press and throwing velocity both in the jump ($p \leq 0.001$) and in support with three steps ($p \leq 0.001$).

Despite the above, some studies conclude that training the rotator cuff muscles is necessary to focus on preventing overuse injuries in this joint, due to its stabilizing function of the humeral head (Andersson, Bahr, Clarsen, & Myklebust, 2017; Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014; Asker, Holm, Källberg, Waldén, & Skillgate, 2018; Andrade et al., 2013), rather than improving throwing velocity. The correlation between ISR strength and throwing velocity does not seem so clear (Schwesig et al., 2016; Pontaga & Zidens, 2014; da Silva, Penido, Pereira Junior, de Souza, & Villaverde, 2014).

There is research in the scientific literature that measures ISR strength in different ways, although for now, never in an isotonic way. Hams, Evans, Adams, Waddington, & Witchalls (2019) measured ISR isometric strength with the Powertrack II Commander HHD handheld dynamometer (PowerTrack™ II Commander; JTECH, Medical), on water polo players. The subjects had to sit in a standardized position with hips and knees at 90° and feet on the ground. The measurements were taken in two positions. In the first, the arm was placed so that the elbow was against the body and the shoulder at 0° abduction, the elbow was bent to 90° and the forearm was in a neutral position. In the second, the shoulder was at 90° of abduction, 90° of external rotation and the elbow was bent 90°. The REV 9000 dynamometer (Technogym, Gambettola, Italy) was used by Pontaga (2018) and Pontaga & Zidens (2014) to evaluate in a isokinetic way the ISR strength in handball players. The athletes performed the measurements in a seated position, with the shoulder abducted at 90º and the elbow flexed at 90º. Other dynamometers, such as the functional electromechanical pulley Haefni Health, have also been used to evaluate the isometric ISR strength of the shoulder (Chamorro, de la Fuente, Rubio, Campos, & Chirosa, 2019). Participants were placed lying supine, arm in the frontal plane at 90° of abduction, elbow bent at 90° in the sagittal plane and forearm in pronation. The option proposed in this study is the Dynasystem functional electromechanical dynamometer (SYMOTECH, Granada, Spain), which allows us to make a more functional evaluation of the force when standing. This dynamometer has not been used to date to evaluate the strength of the shoulder rotators, although it has been used for the trunk flexure strength (Rodriguez-Perea et al., 2019) and the lower extremities strength (Jerez-Mayorga et al., 2019).

This study aims to check if there is a correlation between the ISR strength of the dominant arm's without previous countermovement action, measured in an isotonic way by a new device (Dynasystem), with the standing throwing velocity in handball. Compare if there are correlations between different variables as F0 and V0 of the Force-Velocity profile obtained with both the mean and the peak velocity of ISR, with the mean and peak velocity of handball throwing to goal. The hypothesis is that there is no correlation between the ISR strength and the standing throwing velocity in handball.

2. METHOD

2.1 Participants

A transversal study of repeated measurements was carried out with twenty handball players from the First National category of Spain (mean ± SD; age: 19.28±2.55 years, weight: 81.52±9.66 kilograms, height: 185±6 centimetres, BMI: 23.74±1.69) (Table 1), who participated voluntarily. All participants were informed about the research design, objectives and risks associated with the procedure before giving written consent to participate. Subjects who reported more than 10 years of experience as a federated handball player, no shoulder pain or pain in the past 5 months, and no use of ergogenic aids during or before the measurements, were selected for the study. Subjects were told not to exercise both the day before and the day of the measurements to avoid the effects of fatigue. The study protocol was approved by the Institutional Review Board of the University of Granada (n. 350 / CEIH / 2017) and was conducted in accordance with the Helsinki Declaration.

2.2 Instruments

ISR strength was evaluated with the Dynasystem (SYMOTECH, Granada, Spain) research functional electromechanical dynamometer with an accuracy of three millimetres for displacement, 100 g for a detected load, a sampling frequency of 1,000 Hz and a speed range of 0.05 m/s to 2.80 m/s, coupled to a self-made platform to support the arm with 90-degree shoulder abduction. The throwing velocity was measured on an indoor track using a portable radar gun (Stalker sport 2, Applied Con-Concepts Inc, USA) with an accuracy of 0.1 km / h, and a regulation handball ball size 3 (480-500 grams weight and 56-58 centimetres circumference). Body mass was measured on players wearing underwear with a Tanita SC-330 body composition analyzer (Tanita Corporation, Japan), with a measurement error of 0.1 kg.

Figure 1. Dynasystem dynamometer

Figure 2. *Radar Gun Stalker Sport*

Figure 3. *Tanita SC-330*

2.3 Procedure

2.3.1 Throwing Velocity

After a standardized 10-minute warm-up consisting of jogging, dynamic stretching and technical skills (passing and throwing at submaximal velocities), participants were instructed to perform 8 standing throws from the 7-meter line of the handball court at maximum velocity without run, in goal. A 10" break was left between throws made with the dominant arm.

The evaluator stood behind the goal with the radar gun to measure the throwing velocity, which was set to "peek mode" to detect the maximum velocity of the ball, between 40 and 225 km/h. Before the measurements, the radar gun was calibrated according to the manufacturer's specifications.

Figure 4. Throwing Velocity Measurement

2.3.2 Internal shoulder rotation strength

After a standardized 10-minute warm-up consisting of jogging, dynamic stretching, and joint mobility, an incremental test of 3 to 5 kilograms between series was performed, with 3' to 5' rests, to calculate the ISR repetition maximun of the dominant arm's without previous countermovement. Three repetitions were performed when the speed was greater than 0.90 m/s, two repetitions when the speed was between 0.90 m/s and 0.70 m/s, and one repetition when the speed was less than 0.70 m/s. The Dynasystem functional electromechanical dynamometer was used for this purpose. The test was performed with the participant standing, whose dominant arm would be placed at 90º of abduction in the frontal plane, elbow flexed at 90º in the sagittal plane and forearm in pronation. A self-made stabilizing platform was used to support and position the arm and obtain a rigid fixation to the dynamometer using a strap. The pulley system was placed at 90° between the dynamometer and the participant's forearm. A wrist brace was placed on the participant to fix the rope of the dynamometer pulley. This position was chosen because it is closer to the throwing motion (Bayios, Anastasopoulou, Sioudris, & Boudolos, 2001).

Once the mean and peak velocity at which load of each relative intensity has been moved has been measured, an individual force-velocity profile has been obtained for each player. The study by García-Ramos, Pestaña-Melero, Pérez-Castilla, Rojas, & Haff (2018) confirmed the linearity, precision and reliability of the load-velocity ratio obtained from 3 velocity variables (mean speed, mean propulsive velocity and peak speed) in the press bench launched in the concentric and eccentric-concentric variants only. From the equation of the force-velocity profile line, the variables F0 and V0 have been calculated, both with the mean speed and the peak speed of ISR. Banyard, Nosaka, Vernon, & Haff (2018) concluded that the peak speed, mean speed, and mean propulsive speed are reliable and can be used to develop load-velocity profiles with linear regression adjustments in squat.

Figure 5. ISR Strength Measurement

2.4 Statistical analysis

All statistical analyses were performed using SPSS version 22.0 for Windows (SPSS Inc., Chicago, IL, USA). A Pearson's correlation analysis and the 95% confidence interval were performed to determine the correlations between the dynamometric characteristics of the internal rotator muscles of the dominant arm (F0 and V0 of the Force-Velocity curve with both mean and peak velocities) and the peak and mean throwing velocity of the ball. The significance level was set at $\alpha = 0.05$.

3. RESULTS

The mean and standard deviation of the mean and maximum throwing velocity achieved, as well as the descriptive characteristics of the participants who carried out the study, are shown in Table 1.

Table 1. *Descriptive Characteristics Of The Participants*

	Age (years)	Weight (kg)	Height (cm)	BMI	Mean Throwing Velocity (km/h)	Maximum Throwing Velocity (km/h)
Mean	19,28	81,52	185	23,74	78.45	80.80
SD	2,55	9,66	6	1,69	4.60	5.30

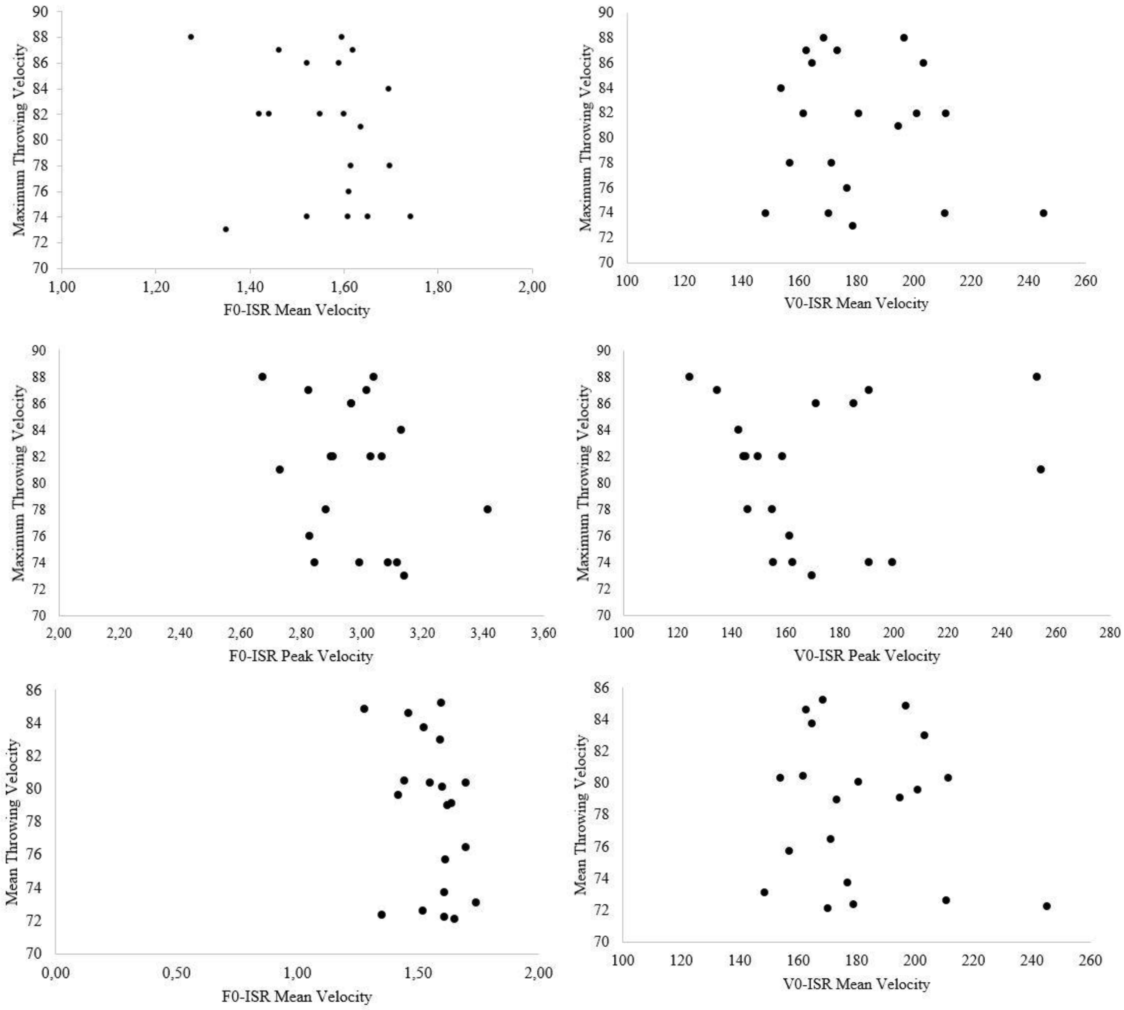
Table 2 contains the mean and standard deviation of the different ISR strength variables, Pearson's correlation and 95% confidence intervals between these ISR force variables and the throwing velocity at goal (mean and maximum) achieved by the players are also presented.

There was no positive correlation between the participants' ISR force variables and the average and maximum throwing velocity (Table 2). Even 8 of the 9 correlations are slightly negative, although not significant. Since the correlations are very close to 0, even one of them is equal to 0, it is understood that it is not possible to determine any sense of covariation.

Tabla 2. *Correlations and interval confidence (95%) between strength variables and throwing velocities, mean and standard deviation of strength variables*

			Mean Throwing Velocity		Maximum Throwing Velocity	
	Mean	SD	Pearson Correlation	Interval Confidence (95%)	Pearson Correlation	Interval Confidence (95%)
F0-Vmed (m/s)	1,56	0,119	-0.32	(-0.68, 0.17)	-0.25	(-0.64, 0.25)
V0-Vmed (N)	181,44	24,44	-0.15	(-0.55, 0.32)	-0.15	(-0.56, 0.31)
F0-Vmax (m/s)	2,97	0,16	-0.22	(-0.60, 0.25)	-0.28	(-0.64, 0.19)
V0-Vmax (N)	169,51	34,81	-0.02	(-0.45, 0.43)	0	(-0.63, 0.63)

As we observe in all the graphs (Figure 6), there does not seem to be any clear pattern of variation between the variables, which is reflected in a scattered cloud of points, far from what could be a straight line. Therefore, no linear relationship can be established between ISR strength and throwing velocity. There is no degree of agreement between the relative positions of the data for the ISR strength variables and the throwing velocity. Therefore, a higher throwing velocity is not achieved at a higher level of force in the ISR of the dominant arm's.



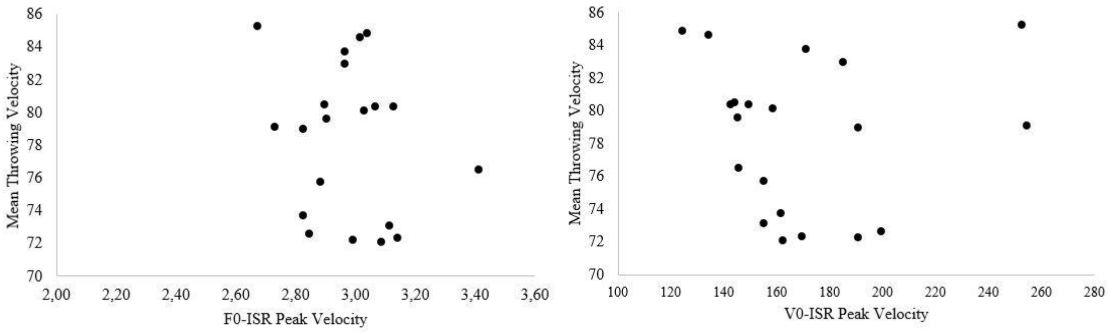


Figure 6. Graphs of the correlations between maximum and mean throwing velocity, and F0 and V0 calculated with both maximum ISR velocity and mean ISR velocity

4. DISCUSSION

The main objective of this study was to check if there is a correlation between the ISR strength, without previous countermovement, of the dominant arm's with the standing throwing velocity without run in handball. The standing throwing was selected because it is the throwing technique with the highest velocity of the ball, being the velocity of the ball the most important performance variable in handball (Gorostiaga, Granados, Ibáñez, & Izquierdo, 2005; Rivilla-Garcia, Grande, Sampedro, & Van Den Tillaar, 2011), regardless of the type of throwing it maintains high reliability. Our results indicate that there is no relationship between the ISR strength data measured with isotonic dynamometry and the throwing velocity recorded by the participants.

This corroborates our initial hypothesis and that described in other research of similar nature. Sarvestan et al. (2019) also obtained no correlation between the isokinetic shoulder strength measured at speeds of 30º/s and 240º/s and the throwing velocity in support from 7 meters, in junior handball players. These findings could be explained by the fact that when players are in contact with the ground, the force transferred through the legs and trunk may be sufficient to reduce the demand on the shoulder joint muscles to develop speed in throwing (Zapartidis, Gouvali, Bayios, & Boudolos, 2007). Besides, horizontal adduction and flexion movements are also produced in the shoulder during the throwing action, in addition to the ISR movement, so these two movements may be more important in achieving higher throwing velocities. Schwesig et al. (2016) obtained very weak correlations between the isometric strength of the shoulder, including among other movements the ISR, with throwing velocity in female handball players. In addition to this, it was also found that maximum joint velocities occurred in a specific order (Wagner, Finkenzeller, Würth, & Von Duvillard, 2014).. Therefore, it is not enough to maximize the speeds and strength in individual shoulder movements, but it is necessary to improve the coordination of the overall throwing movement. Pontaga & Zidens (2014) studied the correlation of concentric isokinetic force (at 60º/s, 90º/s and 240º/s) of ISR and external rotation with throwing velocity in support of adolescent handball players. They only found correlation (r=0.61) between the isokinetic force of ISR at 240º/s with the velocity of throwing in support. Despite this, the authors emphasize more on the importance of training the external rotator muscles of the shoulder, both to provide stability to the joint, and to increase the throwing velocity. The most important role of the rotator cuff muscles is to stabilize the joint. Zapartidis et al. (2007) also found no significant correlation between the isokinetic strength (concentric action at 60º/s, 180º/s and 300º/s) of the ISR and the throwing velocity in support of female handball players in the Greek first division. The only exception was for the peak torque of ISR at 300º/s in the initial measurement. The authors explain that this could be a consequence of inadequate neuromuscular preparation due to the warm-up, so that the throwing movement could not be performed correctly and, as a result, was strongly influenced by the interactions of the movements of the upper extremities. Dauty, Kitar, Dubois, & Potiron-Josse (2005) analyzed the correlation of isokinetic force (at 60º/s and 120º/s) with the throwing velocity from sitting, standing in support and jumping with 3-step run. They concluded that the velocity reached by the ball in handball throwing is not directly influenced by the strength of the shoulder rotators due to the complexity of the technical gesture and the involvement of other large muscle groups of the trunk, pelvis and lower limbs. Bayios et al. (2001) also observed no correlation between the isokinetic force of the ISR at 60º/s, 180º/s and 300º/s and the velocity of 3 types of throwing in players of the first and second Greek handball divisions. The only exceptions were for the ISR at 180º/s (p=0.029) and 300º/s (p=0.048) and the jump shot. Since the existence of these relationships was found to be significant in only one of the three groups of subjects and only in two of the three isokinetic speeds studied in the study, it cannot be suggested that this relationship is generally maintained during the jump throw. During the standing throw, the feet are in contact with the ground, which makes it possible for the force of the lower limbs and the rotation of the trunk to increase the ball velocity by using reaction forces on the ground. On the other hand, during the jumping throwing movement, the player is in the air, which makes it difficult to use the strength of the lower limbs and the rotation of the trunk to increase the velocity of the ball during the throw.

Wagner, Buchecker, von Duvillard, & Müller (2010) showed that low-level players did not reach their maximum angular velocity of ISR until after releasing the ball and that, in defective throwing mechanics, they could reach the peak of ISR after releasing the ball. Reaching maximum ISR speeds after releasing the ball may be one of the reasons for the low correlations observed in the above-mentioned studies of ISR strength and throwing velocity.

These data should be interpreted with care because it is difficult to compare our findings with previous studies of handball players due to differences in study design, measurement methods (isokinetic, isometric or isotonic), age, body mass, skill level (amateur or professional), throwing technique (in support, 3-step throwing, jumping throwing, with or without target) that may affect throwing velocity. The limitation of not having a previous eccentric shoulder rotation contraction to facilitate a stretch-shortening cycle remains in place in this study. Also, the participants only had one familiarization session with the study protocol, which is another limitation to consider, in addition to the sample size.

However, this study is the first to measure ISR strength in an isotonic way, with a functional electromechanical dynamometer (Dynasystem) not used so far. This type of muscle contraction is the same that occurs in competition in the action of the throw, unlike that used in other studies (isokinetic or isometric). Likewise, the strength measurements were made standing up, differing from the methodology of previous studies which made it sitting down, thus achieving greater similarity to the throwing gesture.

Future lines of research are open to study these results. It is of great interest to verify if these results would also be given if the ISR force was measured with a previous eccentric countermove to take advantage of the stretch-shortening cycle, as it happens in the assembly phase of the throwing. In the same way, corroborate this with professional handball players whose anthropometric characteristics are higher and whose strength values are also higher compared to amateur players (Fieseler et al., 2017), so they could achieve higher levels of throwing velocity and ISR strength.

5. CONCLUSIONS

The results obtained in this study lead us to the following conclusions:

There is no correlation between the ISR strength without countermovement of the dominant arm's, measured in an isotonic way, with the velocity of the ball in the standing handball throw without run. Despite having measured the ISR strength of the shoulder in an isotonic way, no correlation with the throwing velocity has been obtained either. In short, higher levels of strength in the ISR of the dominant arm's shoulder does not assure us to achieve higher throwing velocities in handball.

The throwing gesture to the goal is very complex and depends on many factors (force, kinematics of the throw, anthropometric measures of the players, type of throw, level of opposition and precision) as to reduce the obtaining greater or smaller throwing velocity to the internal rotators of the shoulder.

Since the maximum joint velocities in the throwing gesture occur in a specific order (Wagner, Finkenzeller, Würth, & Von Duvillard, 2014), it is not sufficient to maximize the speed and strength in the ISR, but it is necessary to improve the coordination of the overall throwing movement to achieve greater velocity.

It is necessary to look for another way of evaluating ISR with a more open gesture that allows for greater muscle coordination and the benefit of the stretch-shortening cycle.

More studies and research quantifying physiological characteristics in handball players are needed to relate them to performance.

6. RESEARCH APPLICATIONS

It is not necessary to implement a specific training program aimed at increasing the strength of the internal rotators of the shoulder to achieve greater throwing velocity. It is more advisable to train the strength of large muscle groups, in symbiosis with specific throwing training to increase the ball velocity. Rotator shoulder muscle training should focus on stabilizing the joint during movement and preventing joint injuries, as its main function is the dynamic stability of the humeral head during active movements of the upper extremities (Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014; Andersson, Bahr, Clarsen, & Myklebust, 2017).

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9. ANNEXES

Infographic of the study designed by The Voice Of Science