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EFFECT OF ISOKINETIC SHOULDER PERFORMANCE, ELECTROMYOGRAPHIC ACTIVATION AND THROWING VELOCITY ON SHOOTING ACCURACY IN ELITE MALE HANDBALL PLAYERS

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ABSTRACT

In this study the isokinetic shoulder strength, muscular activation and throwing velocity parameters of elite handball players and their relationship with shooting accuracy was determined. Seventeen (17) male handball players (age: 23.17±3.10 years; weight: 85.52±13.48kg; height: 184.35±6.56cm) participated in the study. The isokinetic test was administered with an isokinetic dynamometer system in the shoulder internal and external rotation (IR-ER) movements during the concentric mode (90°/s, 180°/s and 240º/s). Electromyographic activations and throwing velocities were recorded during the shooting accuracy protocol. Simple linear regression and logistic regression analysis were used to determine the effect of the measured parameters on the shooting accuracy rate. Peak torque (PT) variables at the shoulder IRs 90°, 180° and 240° angular speeds had an adverse effect on the shooting accuracy (p=0.029; p=0.037; p=0.033 respectively). There was no relationship between muscular activation, throwing velocity variables and shooting accuracy (p>0.05). It seems to indicate that shoulder IR PT variables have an adverse effect on throwing accuracy. The development of shoulder area muscles with appropriate loads, which have a major effect during shooting, should be taken into consideration by personal trainers and coaches.

Keywords: Handball; Shooting; External rotation; Internal rotation; Muscle activation; Velocity.

INTRODUCTION

Handball is a team sport in which there are intense loads on human anatomy during training and competition, and severe body contacts occur between athletes (Ravier & Demouge, 2016; Hermassi *et al.,* 2019). Although it is basically a throwing sport, the most important feature of handball that distinguishes it from other throwing sports concerning throwing is that the ball is thrown by hand with many different forms and variations. These variations depend on the stepping made for throwing, whether throwing is made by jumping, and many other factors (Skejø *et al.,* 2019).

As the final aim of the handball game is to score more times than the opponent, throwing performance and technique seem to be major key skills for success in competitive handball, with the effectiveness of a shot primarily affected by two factors: throwing velocity and accuracy (Raeder *et al.,* 2015; Akyüz *et al.,* 2019; Makaraci, 2021). At this point, it is reported that optimised accuracy in the range of expert players’ shooting velocities in throwing sports is between 75% and 85% of their maximum speed (Freeston & Rooney*,* 2014). Throwing at a maximum or close to a maximum velocity is important to ensure the shooting accuracy. However, accuracy may not always take place in this way. Thus, constant throwing exercises performed by athletes to ensure the accuracy and throwing velocity take an essential place in terms of increasing the effectiveness of shots (Ortega-Becerra *et al.,* 2018). Although training exercises are more suitable in terms of measurement, the learning effect is also thought to affect performance positively. However, most of the studies are focused on obtaining results with training applications (Wagner *et al.,* 2014).

It is a fact that an athlete who plays handball at a high level should attach importance to the development of the upper extremity and it should not be ignored. Hence, during the handball competition that requires a high level of endurance, the strength parameter also gains importance to minimise the effects on throwing technique and mechanics (Zapartidis *et al.,* 2007; Chaouachi *et al.,* 2009). One of the methods of measuring muscle torque and power is isokinetic dynamometry. Isokinetic measurements are used in the sports literature because they produce highly objective data and focus only on the muscle group being measured during the test (Xaverova *et al.,* 2015; Bonetti *et al.,* 2019). The shoulder internal-external rotator (IR-ER) muscles have been investigated in many studies because they are important for providing joint stability. Since the role of the shoulder IR-ER muscle group is significant in high ball-throwing speed in handball, it seems important to investigate it in handball players (Pontaga & Zidens, 2014).

It is known that electromyography (EMG) measurements are frequently used to determine the level of muscle activation in terms of quantity (number) in sportive activities (Rousanoglou *et al.,* 2015). It is observed that studies using EMG are mostly carried out to determine the contraction strength of muscles. The determination of the activation levels of the muscles in the shoulder girdle (throwing arm side) while throwing in handball, as well as the association of the data obtained as a result of the isokinetic strength measurement with the shooting accuracy appear to be a subject that has not been addressed comprehensively in the handball literature.

PURPOSE OF RESEARCH

Based on the above-mentioned background, this study's goal was to determine the isokinetic shoulder strength, muscular activation and throwing velocity parameters of elite handball players to determine their relationship with shooting accuracy.

METHODOLOGY

Experimental approach

A transversal study design was used to investigate the effects of isokinetic shoulder strength, muscular activation and throwing velocity on shooting accuracy in elite male handball players. The study differs from other similar studies because all tests were applied to the same participant group. A total of 17 (n=17) competitive male handball players (having handball training three times per week and one match a week) participated in the study. A power analysis was performed using data obtained from the previous similar studies (Wagner *et al.,* 2011; Pontaga & Zidens, 2014; Plummer & Oliver, 2017; Eriksrud *et al.,* 2019), and it was determined that 17 participants were required to have a power of 0.95 at $\alpha=0.05$.

Participants

Seventeen (17) Turkish, elite male handball players (age: 23.17±3.10 years; weight: 85.52±13.48 kg; height: 184.35±6.56 cm; training experience: 11.47 ± 1.8 years; 3 left-handed) who actively play in the Turkish Handball Federation (THF) Super League and/or 1st League volunteered to participate in the study. The exclusion criteria were musculoskeletal or neurological dysfunction or injury in the past six months, the inability to participate in standard handball and throwing activities, and ache or discomfort reported throughout the testing (Zapartidis *et al.,* 2007; Eriksrud *et al.,* 2019).

Administrative procedure

All the participants participated in a laboratory familiarisation visit to introduce the testing or training procedures and also to ensure that any learning effect was minimal for the baseline measurements. Players completed tests for shooting accuracy and isokinetic strength of shoulder rotators (internal and external rotation). Furthermore, during the shooting accuracy protocol, the EMG measurements and throwing velocities of the shots were recorded. To reduce the interference of uncontrolled variables, all the participants were instructed to maintain their usual way of life and routine diet programme intake before and during the study. Moreover, the participants were told to refrain from severe exercise for 24 hours and to consume their last meal at least 3 hours before the test time. During the training session and testing, only water was allowed as a drink (Raeder *et al.,* 2015; Haddad *et al.,* 2019).

Ethical approval

Ethical approval (2016/399/23/12/2016) was obtained from the Clinical Research Ethics Committee of Ondokuz Mayıs University (OMU), in accordance with the Declaration of Helsinki. The experimental procedures, potential risks and benefits of the study were thoroughly explained to all participants, and they all gave their written informed consent. The subjects were assured that they could withdraw from the tests without penalty at any time. All tests and measurements were conducted in the athletic performance laboratory and sports hall of OMU, Yaşar Doğu Faculty of Sport Sciences immediately after the end of the season.

Data collection measures

Determination of descriptive information

A portable bioelectrical impedance analyser (Jawon Gaia 359 Plus) was used to record the height and weight parameters of the subjects. Before the measurements, the device was introduced to all the subjects, and they were asked to stay as silent and immovable as possible during the test. The subjects stood on the analyser with bare feet, wearing sport clothes and their height (cm) and weight (kg) values were recorded.

Shooting accuracy protocol

To determine the shooting accuracy rate, the tests used in similar studies on the subject were examined, and the researchers prepared a test protocol according to the subject profile and study design (Andrade *et al.,* 2010; Garcia *et al.,* 2017). The subjects performed a total of ten jumping shots, including five shots to each of the 50x50 holes (target) opened in the left and right upper corners relative to the participants' perspective of the standard handball goal (2x3m) all of which were covered with canvas (Figure 1).

The target areas were chosen as the goal area's extreme points (right and left upper corners), which was most likely to give rise to differences in the movement form of players (Bourne *et al.,* 2011; Akyüz *et al.,* 2019). Lower corners were not used in the test protocol to prevent their potential positive effect on throwing accuracy, since they were contiguous to the ground and increased the difficulty of accuracy. The shooting accuracy protocol was limited to a total of 10 shots due to both the objective of avoiding tiredness and the fact that EMG recordings were made by an electrical cables device.

The subjects performed a 10-minute general warm-up and trial shots at a handball field following the international competition conditions. They were asked to perform jumping shots (a 3-step running throw) to the handball goal since it is the most common shooting technique in handball (Ghosh & Mondal, 2017). To ensure that shooting accuracy protocol shots' velocity did not differ significantly from the trials, all trial shots' velocity was recorded, and no difference was observed.

For jumping shots, the players made a preparatory 3-step run before jumping vertically, 9m from the goal, and releasing the ball while in the air (Wagner *et al.,* 2012). While throwing, the subjects were asked to use the correct technique and throw as accurately as possible (Van den Tillaar & Ettema, 2003; Rousanoglou *et al.,* 2014). An International Handball Federation standard size ball for men's handball (Select, Denmark) was used for all throws. Accurate and inaccurate shots were recorded. Furthermore, a "Stalker Sport 2" radar gun was used (transmitter mode on) to determine the throwing velocity (Figure 1). The device was positioned next to the upper corners of the goal to obtain the most accurate measurements. The velocity of each shot was recorded separately and associated with successful and unsuccessful shots.

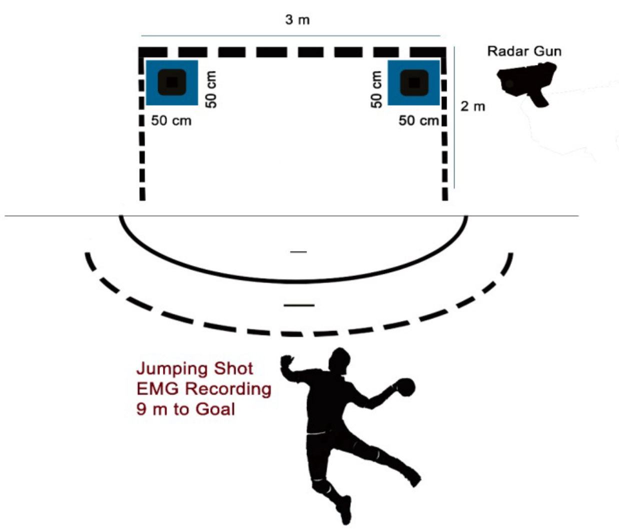

Figure 1. **SHOOTING ACCURACY PROTOCOL**

Isokinetic testing

The dominant-shoulder IR and ER were assessed using a dynamometer (model Cybex HUMAC NORM; Computer Sports Medicine, Inc, Stoughton, MA). Before isokinetic testing, 5-min general warm-up exercises were performed individually (Mascarin *et al.,* 2015; Andrade *et al.,* 2016). During the test, the subjects were supine, with the upper extremity abducted to 90° on the frontal plane and the elbow flexed to 90°. Restraining straps were placed across their pelvis and chest. The range of motion was standardised from 60° of IR to 60° of ER. The isokinetic speeds were 90°/s (5 repetitions), 180°/s (5 repetitions) and 240°/s (5 repetitions) in the concentric mode. These testing procedures were preceded by warm-up concentric repetitions at 120°/s and three submaximal familiarisation trials at the selected speed. Successive testing velocities were separated by one minute of rest (Forthomme *et al.,* 2018).

To make the measurement more objective, gravity compensation was turned on while setting the measurement parameters, and the person's arm was taken into the horizontal position before the measurement started, and the weights of the person and the device were determined. The gravity effect was eliminated during the test (Shahpar *et al.,* 2019). During the isokinetic evaluation, no subject reported pain that could have altered the maximal force exerted. The isokinetic testing enabled the measurement of peak torque (PT in newton metres), and agonist-to-antagonist ratios (IR/ER) were determined applying the same speed and contraction mode for the agonist and antagonist muscle groups.

EMG measurement

The EMG measurement was performed during the shooting accuracy protocol. For the measurements, four muscles (superficial) in total were used in the shoulder IR and ER movements on the throwing arm side while shooting. For the ER movement, the m.infraspinatus (MI) and m.posterior deltoid (MPD) were selected, while for the IR movement, the m.latissimus dorsi (MLD) and m.anterior deltoid (MAD) were selected (Escamilla & Andrews, 2009). After the skin preparation (shaved, cleaned with alcohol and rubbed with fine sandpaper) to reduce the inter-electrode resistance before the electrodes were attached to the skin, bipolar, Ag/AgCl surface electrodes (sEMG; Blue sensor Ambu, Denmark) were placed along the longitudinal axis of the muscle belly in accordance with the SENIAM guidelines by an expert physiotherapist (Hermens *et al.,* 2000).

An EMG device (Biomonitor ME6000, Mega Electronics Ltd., Kuopio, Finland) was fixed to the waist of the subject with the help of a belt. After the device was made ready for testing, the subjects performed their shots. The device was started with the "start-stop" commands at each shot and stopped as soon as the shooting ended. Furthermore, the cables and electrodes were checked after each shot not to create an artefact at the time of the shot. All EMG signals were visually monitored during the data collection, and the EMG signals were acquired at a sampling rate of 1000Hz with specifically created computer software (MegaWin 3.0).

In this study, the root means square (RMS) value was used since it is a parameter that better reflects the level of muscle activity at rest and during contraction. Therefore, it is one of the most widely used parameters in scientific studies (Fukuda et al., 2010). Only the maximum and minimum muscle contraction RMS values were used during the whole shooting period not to evaluate the different contractions not related to the shooting between the onset and the end of the shot (Taha *et al.,* 2015).

Analysis of data

SPSS 21 statistical package software was used in the analysis of the data obtained. Simple linear regression was used to determine the effect of the isokinetic strength variable on the shooting accuracy rate. Logistic regression analysis was used to determine the effect of the throwing velocity and muscle activation variables, which have a direct effect in each shot, on the shooting accuracy rate. The study results were expressed as beta, exp (beta), r-square (rs), standard error (SE), standard deviation (SD), classification success (CS) F and p-values with the significance level accepted as p<0.05.

RESULTS

The shoulder isokinetic performances (IR, ER and IR/ER ratio), EMG activations (RMS/μv) and throwing velocity (km/s) values of the subjects (descriptive statistics) are presented in Table 1.

***Table 1*. DESCRIPTIVE STATISTICS OF PARAMETERS MEASURED**

Parameters	Min	Max	Mean±SD
IR-Peak-90° (N/m)	43.0	106.0	65.88±14.70
ER-Peak-90° (N/m)	27.0	61.0	46.00±8.88
IR/ER Ratio-90° (N/m)	62.0	86.0	72.24±6.33
IR-Peak-180° (N/m)	38.0	104.0	57.76±15.59
ER-Peak-180° (N/m)	24.0	54.0	40.06±8.81
IR/ER Ratio-180° (N/m)	59.0	93.0	72.23±9.33
IR-Peak-240° (N/m)	37.0	99.0	54.70±14.83
ER-Peak-240° (N/m)	24.0	49.0	36.23±8.05
IR/ER Ratio-240° (N/m)	53.0	85.0	68.76±9.28
MLD max (RMS/μv)	56.0	970.0	147.20±134.30
MI max (RMS/μv)	60.0	861.0	132.40±128.53
MPD max (RMS/μv)	56.0	785.0	188.20±139.37
MAD max (RMS/μv)	52.0	763.0	142.20±144.47
Throwing velocity (km/s)	75.6	166.7	107.40±9.85

The isokinetic shoulder strength measurements show that 90° (N/m) has the highest results in both IR and ER when compared to 180° (N/m) and 240° (N/m). In EMG measurements, it was found that MLD was the most active muscle. During throwing, it was revealed that the maximum, minimum and average velocity of the shots was 166.70 (km/s), 75.60 (km/s) and 107.40 (km/s), respectively.

As a result of the simple linear regression test, the peak torque variables at the shoulder internal rotation 90°, 180° and 240° angular speeds were determined to have an adverse effect on the shooting accuracy rate (p= 0.029; p= 0.037; p= 0.033, respectively) (Table 2).

IR-Peak-90°, IR-Peak-180° and IR-Peak-240° variables had an adverse effect on the accuracy rate that was statistically significant (Table 2). There was a negative effect of ER-Peak-90°, IR/ER Rate -90°, ER-Peak-180°, IR/ER Rate-180°, ER-Peak-240° and IR/ER Rate-240° variables on the accuracy rate, but no statistically significant difference was observed (p>0.05).

***Table 2*. SIMPLE LINEAR REGRESSION OF ISOKINETIC SHOULDER STRENGTH AND SHOOTING ACCURACY**

Parameters (N/m)	Beta	rs	S.E.	F	p
IR-Peak-90°	-0.07	0.28	1.58	5.852	**0.029***
ER-Peak-90°	-0.06	0.07	1.79	1.236	0.284
IR/ER Ratio-90°	-0.03	0.01	1.85	0.213	0.651
IR-Peak-180°	-0.06	0.25	1.61	5.210	**0.037***
ER-Peak-180°	-0.06	0.08	1.78	1.468	0.244
IR/ER Ratio -180°	-0.05	0.06	1.81	0.971	0.340
IR-Peak-240°	-0.06	0.27	1.59	5.536	**0.033***
ER-Peak-240°	-0.06	0.06	1.80	1.052	0.321
IR/ER Ratio 240°	-0.05	0.06	1.80	1.066	0.318

*p<0.05

As a result of the logistic regression test, no relationship was found between EMG activation, throwing velocity variables and shooting accuracy rate (p>0.05) (Table 3). It was observed that MLD max, MPD max and MAD max variables had a positive effect on the accuracy rate, but there was no statistically significant difference between them (p>0.05). Although MI max and throwing velocity variables had an adverse effect on the accuracy rate, no statistically significant difference was observed (p>0.05).

***Table 3*. LOGISTIC REGRESSION OF EMG ACTIVATION, THROWING VELOCITY AND SHOOTING ACCURACY**

Parameters	CS (%)	p	Exp(Beta)	Beta
MLD max (RMS/µv)	52.9	0.586	1.001	0.001
MI max (RMS/µv)	51.8	0.667	0.999	-0.001
MPD max (RMS/µv)	57.6	0.130	1.002	0.002
MAD max (RMS/µv)	59.4	0.069	1.002	0.000
Throwing velocity (km/s)	54.7	0.500	0.989	-0.011

The average velocity of 82 accurate shots was 107.9 (km/s) and the average velocity of 82 inaccurate shots was 106.8 (km/s) (Table 4).

***Table 4*. AVERAGE VELOCITY FOR ACCURATE AND INACCURATE SHOTS**

Parameters	n	Mean±SD
Accurate (km/s)	88	107.9±10.51
Inaccurate (km/s)	82	106.8±9.13

DISCUSSION

The goal of this study was to determine the isokinetic shoulder strength (isokinetic), muscular activation and throwing velocity parameters of elite handball players, which affect their shooting performance, and to investigate the relationship of the said parameters with shooting accuracy. The results of the present study show that the peak torque variables at the shoulder internal rotation 90°, 180° and 240° angular speeds were determined to have an adverse effect on the shooting accuracy rate (p=0.029; p=0.037; p=0.033, respectively). However, no relationship was found between muscular activation, throwing velocity variables and shooting accuracy rate (p>0.05).

Isokinetic shoulder performance and shooting accuracy

When studies in the literature were examined, considering the subject's profile, age, gender and other factors used, it is observed that IR and ER PT values at different angular speeds are parallel with the data obtained in the current study (Bayios *et al.,* 2001; Mascarin *et al.,* 2015). This confirms the suitability of the subject profile used in the study.

According to the study results, in the measurements performed at angular speeds of IR 90°, 180° and 240°, it was observed that the PT strengths applied by the subjects had a statistically negative effect on the shooting accuracy (Table 1). It can be concluded that the increase in strength that will be applied while throwing may reduce the accuracy rate of athletes who play handball at the elite level in parallel with the current shoulder isokinetic strength values. Zapartidis *et al.* (2007) did not determine a relationship between shoulder IR and ER PT values and shooting effectiveness (velocity/accuracy) in handball players. In another study, Raeder *et al*. (2015) did not observe a change in the throwing performance of female handball players as a result of 6-week medicine ball training. For handball players playing at the top level, it is known that players can control the throwing strength, which is claimed to be needed for a more effective shot (Chaouachi *et al.,* 2009).

In the present study, shoulder IR and ER PTs do not have a positive effect on the shooting accuracy. Nevertheless, it is known that when the handball sport is considered as a whole, strength takes an essential place in applying the technique in the most accurate and fastest way (Khaled *et al.,* 2018). Since players naturally want to throw in the strongest and fastest way while shooting in the handball game, they can benefit from their experience acquired over the years and improve their throwing techniques (especially by actively using the wrist) to achieve the optimum performance.

EMG activation and shooting accuracy

According to the results of the present study, the muscle with the highest activation level was the MPD, which was followed by the MLD, MAD and MI (Table 1). Taha *et al.* (2015) examined the activation levels of some muscles in the upper extremity during the jumping shot in handball. Furthermore, Alizadehkhaiyat *et al.* (2015) examined the activation status of the muscles in the shoulder girdle during the IR movement. In both studies, the researchers determined that the muscle with the highest activation level was the m.deltoid (medial section).

When the relationship between muscle activation and shooting accuracy rate was examined, no statistical difference was found between the muscles for which the measurement was performed and the accuracy rate (p>0.05) (Table 3). It can be speculated that the adverse effect of the MI on the shooting accuracy rate may be due to the fact that this muscle is involved in ER. In other words, it moves in the opposite direction of the throwing (shooting) mechanics towards the goal. This is because the player concentrates on the forward swing (IR) to throw the ball faster, i.e. the shooting phase, rather than the retraction phase (ER) of the throwing arm. The more muscle fibres a motor unit has, the stronger the contraction is.

The fact that the MPD, which is involved in ER, is positively correlated with the shooting accuracy can be explained by the fact that this muscle is part of the deltoid muscle group that is used extensively while throwing (Pontaga & Zidens, 2014) and also has a small muscle surface (less muscle tension). The reasons for the fact that the MLD and MAD involved in internal rotation have a positive effect on the shooting accuracy, may be stated as the fact that the MLD, located in the posterior part of the body, is active in the process of throwing (IR) and that this tension directly affects the throwing mechanics and the fact that the MAD is a part of the deltoid muscle, as mentioned in the MPD.

In another study, Rousanoglou *et al*. (2014) examined the EMG responses in the different phases of a basic high shot in handball. According to the results of the study, although a positive relationship was determined between the shooting velocity and accuracy in handball players in the elite group, this was not related to the muscular activation. In a different study, conducted by Taha *et al.* (2017) on archers, it was found that the m.extensor digitorum, which exhibited high activation during the shooting in archery, affected the shooting performance significantly (positively).

According to the previous studies and the current findings, exercises aimed at the development of the m.deltoideus group that shows the highest activation (especially the medial part) during throwing are important for strengthening the shoulder girdle muscles, which are among the muscle groups with the highest risk of injury, as well as making the shot faster and more accurate.

Throwing ball velocity and shooting accuracy

In the present study, it was observed that the players' average jumping shot velocity (107.40±9.85km/h) (Table 1) was similar to the results of the other studies conducted with handball players playing at the same level (Rivilla-Garcia *et al.,* 2011; Rivilla-Garcia *et al*., 2016). There are many factors that affect the throwing velocity during the jumping shot performed with the highest velocity after the standing shot that was also used in the current study. These include gender, the position of the arm while throwing, the level of players and the weight of the ball (Skejø *et al.,* 2019). Therefore, the comparison was performed within the framework of these factors.

According to the findings of the study, it was observed that the average velocity data for accurate and inaccurate shots were also very close to each other but did not show statistical significance (Table 3, Table 4). Van den Tillaar and Ettema (2006) reported in their study that there was not a significant relationship between ball velocity and accuracy during the penalty (7-metre) shot. Van den Tillaar and Ettema (2006) and Garcia *et al*. (2013) emphasised that there was a relationship between throwing velocity and accuracy. Based on the reason for our study results, which are similar to the literature in general, athletes do not directly target the concept of accuracy while performing their shots during the competition and the test.

Naturally, a handball player at every level focuses more on the throwing velocity while throwing, because the idea that a high-velocity shot cannot be prevented by the defence or the goalkeeper, is a recognised fact in handball (Ferragut *et al.,* 2018). Considering the concept of shooting accuracy in handball, it has been previously discussed in different studies that handball players, especially those playing at the elite level, show positive results in relation to shooting velocity and shooting accuracy compared to younger (inexperienced) handball players (Laffaye *et al.,* 2012; Rousanoglou *et al.,* 2014).

Because the concept of accuracy is not a condition that can be explained only by the throwing velocity, the finding indicating that there is no relationship between the throwing velocity and shooting accuracy in the current study can be considered normal. To achieve an increase in the shooting accuracy rate, it can be ensured that the throwing mechanics is optimised as a result of including shooting exercises continuously in training by taking into account the throwing velocity variable.

CONCLUSION

This study has demonstrated that the shoulder IR PT variables have an adverse effect on throwing accuracy, while muscular activation and throwing velocity do not. Shooting performance in handball is affected by different physiological variables, such as heart rate, blood pressure and aerobic/anaerobic capacity. Moreover, it should be noted that psychological factors also have a significant effect (both negative and positive) on sports performance. Therefore, the athlete's self-esteem, motivation and some external factors are thought to be directly related to the accuracy of the shot during the game.

Although the study presented useful data by examining different parameters in the same group of subjects, to reveal more clear data on the subject and to increase the quality of the study, factors such as different athlete profiles and the gender variable, as well as the current electrophysiological and biomechanical measurements should be used. Future studies, examining the acute and chronic effect of the factors on shooting accuracy by evaluating the effect of training applications and learning effect model separately may provide valuable findings.

PRACTICAL APPLICATIONS

This study determined the isokinetic shoulder strength, muscular activation and throwing velocity parameters of elite handball players to determine their relationship with shooting accuracy. Considering the adverse effect of the shoulder IR peak power values at different angles obtained according to the results of the study on shooting accuracy, the development of the shoulder area muscles with appropriate loads, which have a major effect during shooting, should be taken into consideration by personal trainers and coaches. It would seem highly advisable to implement exercise programmes providing a balance of shooting velocity and accuracy in routine handball training due to its influence on throwing performance.

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