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Relationship among maximal grip, throwing velocity and anthropometric parameters in elite water polo players

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Aim. **As independent aspects, body size, body composition, and physiological performance of elite athletes have aroused the interest of sports scientists but, unfortunately, studies that combine these aspects are scarcely avalaible in water polo. The aim of the present study was to: 1) to develop an anthropometric profile of highly skilled male Water Polo players, and 2) to identify significant relationships between these features and overhead throwing velocity in highly skilled male water polo players.**

Methods. **Thirteen male water polo players, with a mean age of 26.10±4.82, were recruited from the Spanish Water Polo team and an anthropometric assessment on all of them was carried out. Throwing velocity was evaluated in three different situations from the 5 m-penalty line on the center of the water polo goal: A) throwing without a defender nor a goalkeeper; B) throwing with a goalkeeper only, and C) 3) armfuls running shot with goalkeeper. Maximal handgrip was also tested.**

Results. **Biacromial breadth shows a significative correlation with hand grip in water polo players (r=0.792; P=0.001) and also correlates with Throwing velocity (r=0.716; P<0.001). Biepicondylar femur breadth correlates significatively with hand grip (r=0.727; P<0.05) and also with throwing velocity in "throwing with goalkeeper" situation (r=0.664; P<0.05). Hand grip shows a significant correlation with throwing velocity in "throwing with goalkeeper" situation (r=0.603; P<0.05).**

Conclusion. **In conclusion, body mass aspects are not related with throwing velocity in highly skilled Water Polo players. Maximal hand grip is related with throwing velocity in "throwing with goalkeeper" situation. More investigations about water polo are necessary.**

Key words: **Water polo - Anthropometry - Hand strength.**

Water polo is a very stressful body-contact team sport that places heavy emphasis on swimming, jumping, swimming speed and throwing, and requires substantial strength levels to hit, block, push and hold during game actions.[1] From this, it may be hypothesized that high levels of strength and muscular power are important to a successful participation in elite levels of water polo leagues.

Across the different studies, an ideal profile of each sport has been described. For this reason, today is unquestionable that some anthropometric characteristics are related with high performance in sports. Norton and Olds [2] suggest that in each sport, event and even position within a sport demands its own unique set of physical and physiological attributes for succes at the highest level.

Anthropometric characteristics of elite water polo players have changed along the last 15 years. Body shape has changed in terms of greater height and longer limbs, with thinner waist and broader shoulders, however, body mass remains unchanged and muscle to fat mass ratio has increased.[3] These changes could be due to the enviromental changes in gen-

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eral [3] and to changes in the rules of water polo. Water polo rules have been modified with the intention of creating a faster and more spectacular game, by encouraging more shooting at goal. Today, water polo is played over four periods, the duration of each having been increased from five minutes to either seven or nine minutes, depending on the championsip tournament, and the penalty line has also been changed. It was previously set at 4 m from the goal and now it has been changed to 5 meters.[4] Unfortunately, very few studies have been published about antrophometric profile of highly skilled water polo players.

Skill in passing and throwing is also vital in water polo because accuracy and the ability to produce high velocities are also valuable during the game for shots at goal. The overhead throw pattern is the most effective and frequently used to propelling the ball and scoring goals in water polo.[5] The overhead throw, accounts for up to 90% of all passes and shots during a game. In this pattern, the ball comes from behind the body and is brought up over the head and released in front of the body. The goal of this overhead throw pattern is to achieve high endpoint velocity.[5]

Two basic factors are of importance with regard to the efficiency of shots: accuracy and throwing velocity. Naturally, the faster the ball is thrown at the goal, the less time defenders and goalkeeper have to save the shot.[6]

Ball control in water polo and the shot are also vital in the game. This control is linked to the ability to grip the ball, wich is important in the back swing and therefore the corresponding forward swing and its release velocity.[7]

Many studies have shown that in power sports, technical and tactical skills are vital, but anthropometrical factors, high levels of strength, muscular power and throwing velocity are very importants for succes in these sports.[8-11]

For these reasons, nowadays, coaches are training with a principal aim, to make players bigger, faster and stronger than before. They are trying to develope anthropometrical characteristics and optimize training of specific skills.

The intermittent nature of this sport, together with the limitations imposed by the aquatic environment, makes the assessment of physiological capabilities of water polo players technically difficult.[12] Due to this fact, very few studies concerning the physical and physiological attributes required to achieve world-class performance have been published.[13-15] However, the development of a comprehensive battery of tests that would include both anthropometric and physiological measurements would offer a more integrated profile of the elite water polo player.[15]

The truth is that there is a lack of research on the physical and physiological demands of water polo and therefore the aim of this study was twofold: 1) to develop an anthropometric profile oh highly skilled male water polo players, and 2) to identify significant relationships between these features an overhead throwing velocity in highly skilled male water polo players.

Materials and methods

Thirteen male water polo players aged (26.10± 4.82) were recruited from the Spanish Water Polo team.

The study was approved by the San Antonio Catholic University Committee on research involving human subjects. All participants received verbal and written information about the study and gave written informed consent before anthropometric and conditional assessment.

Additional background information included date of birth, specific position and years of water Polo playing was provided by each player.

International Society for the Advancement of kinanthropometry (ISAK) protocols were used to determine the anthropometric profile of the water polo players.

Subjects were measured during a single measurement session. Unilateral measurements were taken on the right side of the body. Participants wore light clothing (slip) but not shoes.

Physical characteristics were measured in the following order: Height, body mass, arm spam, skinfolds, body girths and skeletal breadths. The anthropometric program included about 30 measurements. Height and weight measurements were made on a levelled platform scale (Seca, Barcelona, Spain) with an accuracy of 0.01 kg and 0.001 m, respectively. Eight skinfolds (triceps, subescapular, biceps, axilar, abdominal, iliac crest, suprailiac, front thigh and medial calf) were measured by Holtain Skinfold Calliper with 10 g/mm^{-2} constant pressure. Ten limb/body girths (arm relaxed, arm flexed and tensed, forearm,

TABLE I.—*Anthropometric characteristics of water polo players (mean ± SD).*

Subject characteristics	
Age (yrs)	26.08±4.76
Mass (kg)	91.53±11.96
Height (cm)	188.19±6.11
Arm span (cm)	195.53±7.29
Experience (yrs)	13.46±3.09
Body fat and lean mass	
BMI (kg*m-2)	26.25±2.74
Body fat (%)	10.91±2.31
Lean mass (kg)	54.33±7.50
Lean mass (%)	59.64±2.63
Breadth (cm)	
Biepicondylar humerus	7.27± 0.76
Biestiloideo wrist breadth (radio-ulnar) / Bistyloid	6.23±0.38
Biepicondylar femur	10.26±0.66
Biacromial breadth	44.80±2.98
Biiliocristal breadth	36.01±2.00
Girth (cm)	
Arm girth relaxed	35.31±2.73
Arm girth flexed and tensed	37.88±2.55
Forearm girth (max. relaxed)	29.90±1.86
Wrist girth (distal styloid)	17.80±0.78
Chest girth	107.98±5.55
Waist girth	87.70±6.04
Gluteal girth	102.28±4.61
Thigh girth	55.45±3.74
Calf girth	37.91±2.11
Ankle girth	23.54±1.59
Somatotype	
Endomorphy	2.99±0.92
Mesomorphy	5.56±1.38
Ectomorphy	2.03±0.96

wrist, chest, waist, gluteal, thigh, calf and ankle) were measured using a Lufkin metal tape, and five skeletal breadths (biacromial, biepicondylar-humerus, biepicondylar, biiliocristal and bistyloid) were measured using an anthropometer (GPM, Switzerland).

Double measures for each of 30 anthropometric dimensions (triple measures for skinfolds) were obtained by one accredited level II and three accredited level I ISAK anthropometrists. The technical error of measurement was <2% for all skinfolds and <1% for all bone breadths and body girths.

Several variables were derived: 1) the body mass index (BMI) was calculated as weight (kg) divided by height (m^2); 2) percentage of body fat was estimated from measurements of skinfold thickness using the method described by Jackson *et al.*;[16] 3) fat free mass (FFM) (kg) using the method described by Martin;[17] 4) selected anthropometric measures were used to determine somatotype following the methods described by Carter *et al.*[18]

In order to assess specific explosive strength production in water polo players, a radar gun (Stalker-Pro Inc., Plano), with 100 Hz frequency of record and with sensibility 0.045 $m \cdot s^{-1}$ was used.

The radar was placed behind the goal post and in a perpendicular direction to the player. The players were invited to perform six shots under three different conditions (two shots in each condition) from the 5 m-penalty line in the centre of the water polo goal. The three conditions included:

1) no defender or goalkeeper;
2) goalkeeper only;
3) three armfuls running shots with goalkeeper.

After a 10-minute standardized warming up, the subjects were instructed to throw a standard water polo ball (mass 450 g, circumference 70 cm) as fast as possible through a standard goal, using one hand and their own technique. For each type of throw, each subject performed trials until two correct throws were recorded, up to a maximum of three sets of three consecutive throws. A 2- to 3-minute rest elapsed between sets of throws and 20-30 seconds elapsed between two throws of the same set. For motivation, players were immediately informed of their performance.

Additionally, Maximal isometric hand-grip force was recorded using a handheld hand-grip dynamometry (T.K.K. 5401, Japan), with a sensitivity of 0.1 kilogram of force (Kgf). The study subjects were familiarized with the dynamometer with three repetitions warming. The players performed two repetitions at maximum intensity with the dominant hand. They did it at a standing position and the dynamometer set parallel to the body. In this position the player was invited to exert maximal grip force without arm or wrist movement. The best trial was used for further analysis. Three minutes rest elapsed between trials in order to minimise the effect of fatigue.

Statistical analysis

Standard statistical methods were used for the calculation of the mean and standard deviations. A one-

TABLE II.—*Hand grip and throwing velocity values of water polo players (mean ± SD).*

	All Players	Wing	Center back	Center foward
Hand grip (N)	44.24±6.64	43.94±5.92*	48.33±6.60	55.36±2.54
Without goalkeeper (m/s-1)	20.53±1.19	20.20±1.10	21.57±1.60	20.28±0.28
With goalkeeper (m/s-1)	20.25±0.92	19.76±0.85	21.02±0.89	20.65± 0.42
With previous displacement (m/s-1)	20.34±0.7	72.57±0.69	20.74±0.97	20.37±0.42

* Significant difference between wing and center forward at P<0.05.

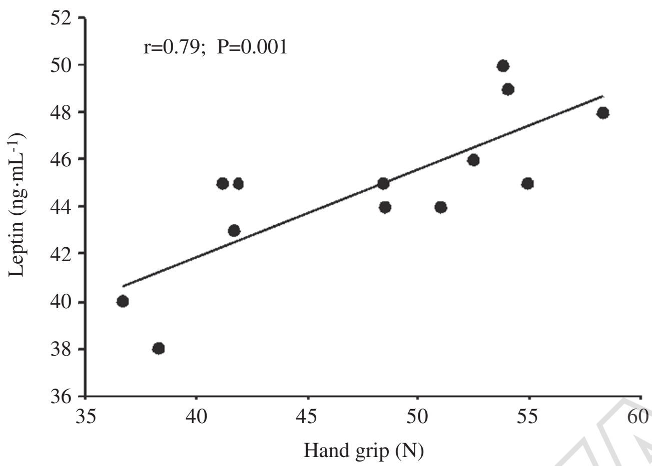

Figure 1.—Relationship between Biacromial breadth and hand grip.

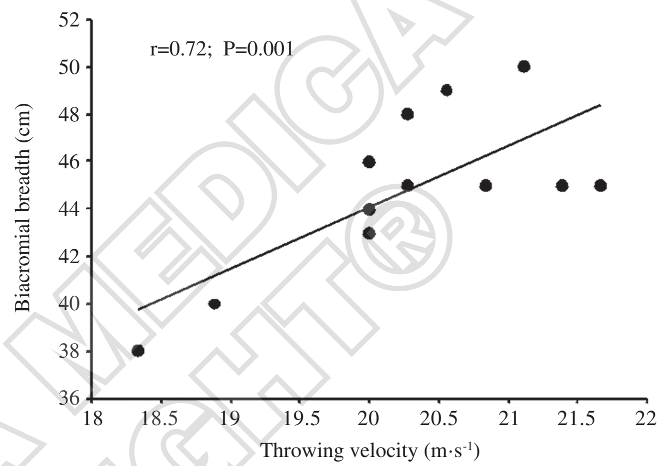

Figure 2.—Relationship between Biacromial breadth and throwing velocity.

way analysis of variance (ANOVA), and a Tukey *post hoc* test was used to study differences among playing positions. Pearson product-moment correlation coefficients (r) were used to determine the relationships of all anthropometric measures with throwing velocity and hand grip. The P≤0.05 criterion was used for establishing statistical significance.

Results

Anthropometric characteristics of Spanish water polo players are presented in Tables I, II.

Mean isometric hand grip of water polo players was 44.24±6.64 N. If we describe the sample by specific playing positions, center forwards show higher values of hand grip strength than wings (P<0.05). No differences were shown between center forward and center back, nor center back and wing. No significant differences in throwing velocity by specific playing positions were obtained in any situations tested. When we analyzed possibles correlations between anthropometric factors and physical fitness, we found that biacromial breadth shows a significative correlation with hand grip in water polo players (r=0.79; P=0.001) (Figure 1), and also correlate with throwing velocity (r=0.716; P<0.001), in "throwing with goalkeeper" situation (Figure 2).

Biepicondylar femur breadth correlates significatively with hand grip (r=0.727; P<0.05) (Figure 3), and also shows significant correlation with throwing velocity in "throwing with goalkeeper" situation (r=0.664; P<0.05) (Figure 4).

Biiliocristal Breadth shows a very strong and significative correlation with hand grip (r=0.838; P<0.001) in Spanish water polo team (Figure 5); and also, shows a strong correlation with biepicondylar Femur breadth (r=0.809; P<0.001).

Hand grip shows a significant correlation with throwing velocity in "throwing with goalkeeper" situation (r= 0.603; P<0.05) (Figure 6).

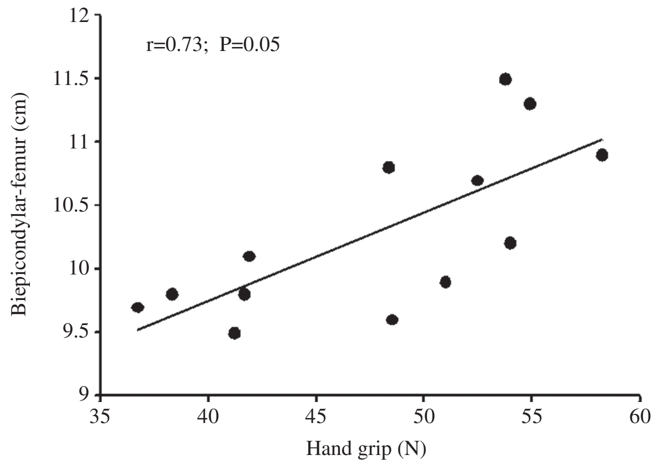

Figure 3.—Relationship between Biepicondylar femur breadth and hand grip.

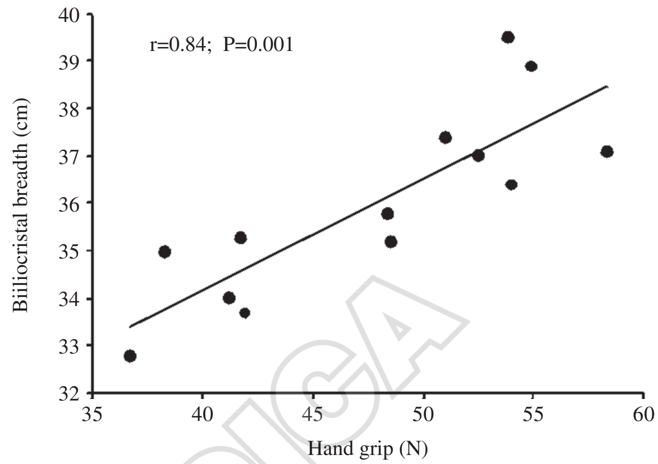

Figure 5.—Relationship between Biiliocristal breadth and hand grip.

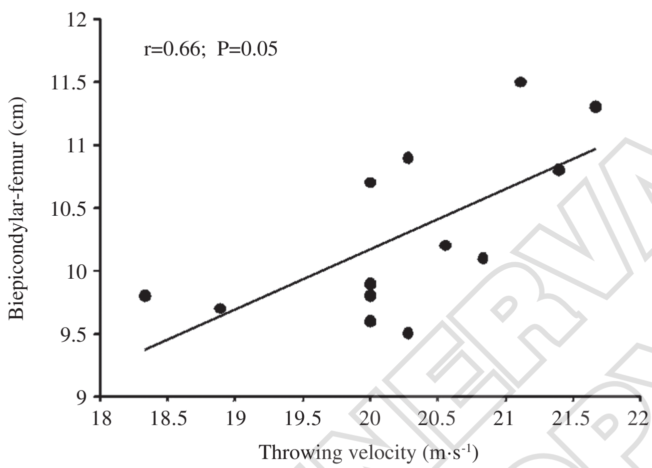

Figure 4.—Relationship between Biepicondylar femur breadth and throwing velocity.

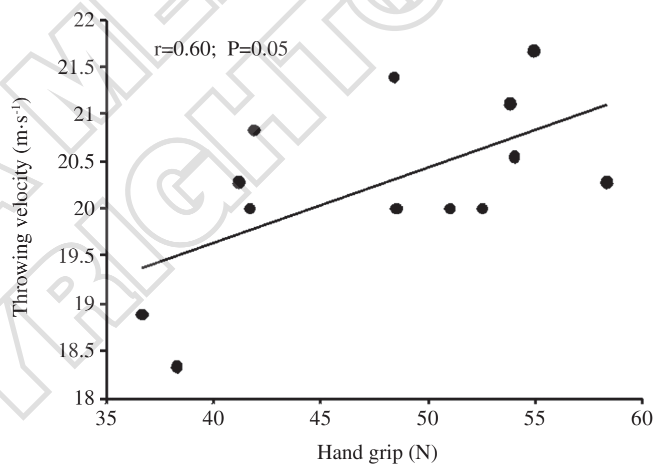

Figure 6.—Relationship between throwing velocity and hand grip.

Discussion

The aim of this study was to investigate the relationship between anthropometric dimensions, throwing velocity and hand grip strength. The results show that anthropometric breadths have a strong correlation with throwing velocity and hand grip strength, whereas, other anthropometric factors are not related with throwing velocity or hand grip in highly skilled water polo players.

Spanish water polo players show a mean ball speed of 20.53 $m.s^{-1}$, significantly greater than others velocities reported. USA national level players obtained an average speed of 19.7 $m.s^{-1}$.[19] These ball speeds have also been found in national level players (18.4 $m.s^{-1}$) and collegiate level players (13.7-18.9 $m.s^{-1}$) [20, 21] and lesser values (16.5-16.87 $m.s^{-1}$) were obtained in Australian players reported by Bloomfield.[5] These differences could be due to the different levels of the sample. Our players are highly skilled players, and throw faster than the other players reported. It could be postulated that at a higher level player shows higher velocity in shot.

We cannot find any differences in throwing velocity nor by specific playing positions, neither by different throwing types. It could have been predicted that ball speed would increase in the presence of goalkeeper, requiring the shooter to shoot the ball faster in order to minimise their time available to block the shot. This hypotesis was not supported by the results. According to the authors, there are only two studies where goalkeeper and throwing velocity were analyzed, and in one of them, the effect of the goalkeeper's presence on the shooting speed was not examined.[22] Our results are consistent with those of Van der Wender *et al*.[7] They cannot find any difference in the throwing velocity, both with and without the goalkeeper.

We found significative correlations between biacromial breadth, and biepicondylar femur breadth with throwing velocity in the situation "throwing with goalkeeper", but we could not find any significative correlations with body mass, upper body lengths or upper body girths. These results are different from those reported by Bloomfield.[5] Bloomfield [5] found several correlations between anthropometrical factors and throwing velocity, but we only found significative correlations between three breadths and only in the situation "throwing with goalkeeper". In the other throwing types, no relationship between anthropometric parameters and throwing velocity were found. However, our results are in line with Bloomfield [5] in relation with biacromial breadth. We found significant relation between biacromial breadth and throwing velocity, showing that upper body breadths are very important in throwing velocity. We also found a positive and significant correlation between femur breadth and throwing velocity. These results are in line with Bloomfield [5] and it could be due to the water polo characteristics. The lack of ground support affects the throw, and water polo players utilise their legs more during the shot, producing more force as the body moves upwards by flexing and extending the legs.[23]

In other sports, significant correlations between anthropometric parameters and throwing velocity have been found. In handball, significant correlations between corrected upper arm circunference (r=0.32), corrected forearm circumference (r=0.55) with throwing velocity.[24]

Maximal isometric hand grip shows a significative correlation with throwing velocity in the situation "throwing with goalkeeper", but no correlations were found in the other throwing situations. Hand grip has been identified as a limiting factor for manual carrying,[25] and in overhead throwing, the player has to hold the ball during the movement. This movement has been analyzed by biomechanics, and it is well documented that the last phase of the overhead throwing is forearm extension and wrist flexion in order to get a more accuracy shot. The kinetic link principle is utilized with the water polo throw, where the hip initiate rotation, the trunk turns towards the target so the momentum generated from these proximal segments is transferred through the arm maximizing the ball velocity. Wrist flexion contributes aproximately 8-13%.[26]

That we found correlations between throwing velocity and hand grip only in the situation with goalkeeper and we could not find correlations in the other situations could be due to the tactical situation of this shot. Maybe in the penalty throw, the size of the ball becomes an important factor, because if we need to direct the throwing in order to score, the ball must be well fixed and the end of the movement will be a wrist flexion. So in this kind of movements, the forearm strength could be very important and it could be related with throwing velocity.

We could not find any similar studies concerning water polo, but we found similar correlations between throwing velocity and hand grip in experienced female pitchers,[27] and only one in handball players.[28]

Biiliocristal breadth and biepicondylar femur breadth show a positive and significative correlation with hand grip, establishing the importance for the lower body segments in water polo players. These results are not consistent with those of others reported.[29, 30] Jurimae *et al*. reported that breadths were not related to handgrip strength in any group. This difference could be due to the different sample used. They analyzed prepuberal children while the children included in this study were older and highly trained.[29, 30]

It is necessary to undertake further investigation about this issue, with a bigger sample, and analyze the throwing velocity in game, playing official championships.

Conclusions

Body mass aspects are not related with throwing velocity in highly skilled water polo players. We could only find significant correlations with throwing velocity for some breadths, aspects that are no modifiable with training.

Maximal hand grip are related with throwing velocity in throwing with goalkeeper situation. More investigations about water polo are necessary.

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