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Section I - Kinsiology

Anthropometry and throwing velocity in elite water polo by specific playing positions

by

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The purposes of this study were threefold: to present the specific physical structure of elite water polo players by playing positions, to access its throwing velocity in different conditions (without goalkeeper, with goalkeeper and with previous displacement), and to observe the relationships between the assessed anthropometric and throwing velocity parameters. Nineteen water polo players of the Spanish National Team (nine offensive wings, five center back and five center forwards) were evaluated. The anthropometric profile (particularly the lengths, breaths, girths and skinfolds) was obtained according to the International Working Group of Kinanthropometry, and the throwing velocity was assessed in 3 x 2 maximal intensity shoots (3 min interval) from the penalty line using a radar. It was possible to observe higher values of body mass, BMI, and muscle mass of the center forwards compared to the wings, and foot length of the center backs compared with the wings, reflecting a specific physical profile for each playing position. However, no difference was found between groups regarding the breadths values. In addition, the somatotype of the wings is a balanced mesomorph, and the center backs and center forwards endo-mesomorphs. Despite center backs have higher hand grip values in comparison with wings, no differences were observed between specific playing positions in each throwing condition, as well as between conditions in each specific playing position. Moreover, observing the correlation coefficient values between anthropometric and throwing velocity variables by specific position for the three throwing conditions, a higher number of relationships was found for the center backs and center forwards rather than for the wings. When the total sample was analysed, a superior number of relationships was observed between the studied parameters in throwing with goalkeeper situation. These data reflects the dependence of the throwing skill on the anthropometric characteristics of water polo players.

Key words: somatotype, muscle mass, strength, throw

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Introduction

Water polo is a complex team intermittent sport, comprising of high and low intensity efforts. As it is also a contact sport, complementarily to swimming, jumping in the vertical plane and receiving, passing and shooting the ball, water polo players must face their opponents through blocking, contacting and pushing (Smith, 1998; Garbolewski and Starosta, 2002; Van der Wende, 2005; Stevens et al., 2010). Indeed, the optimization of the specific physical capacities determinant of water polo performance is a daily concern of coaches, who often refer to the necessity of higher, stronger and faster players. Thus, it is fundamental to study the anthropometric profile of elite water polo players, and to relate it with their specific physical capacities, in order to guide athletes to specialize in various playing positions (Aleksandrović et al., 2007; Lozovina and Pavicic, 2004; Mészáros et al., 1998; Tan et al., 2009).

The anthropometric profile of water polo players has been an area of great interest in the scientific community, namely due to the modifications caused by training, and to the establishment of comparisons between teams (Andreoli et al., 2001; De Lorenzo et al., 2000; Fleck, 1983; Frenkl et al. 2001; Lozovina and Pavicic, 2004; Sands et al., 2005; Tsekouras et al. 2005). However, the number of studies that relate anthropometric and conditional characteristics focusing in the eventual different water polo player characteristics by specific playing positions are scarce (Pavicic et al., 2000; Platanou and Geladas, 2006; Tan et al., 2009).

From the several abilities that influence water polo performance, throwing seems to be one of the most decisive (Smith, 1998; Van der Wende, 2005; McCluskey et al., 2010; Stevens et al., 2010). Following Joris et al. (1985) and McCluskey et al. (2010), the velocity of the ball in the throwing movement has a decisive effect on the final result, since the faster the movement, the more difficult is its interception by the defenders and goalkeeper. Knowing that throwing velocity seems to depend on muscular strength and technique through precise synchronization of different body segments, the literature has been centred in the biomechanical analysis of penalty throws (Carys and Lewillie, 1970; Clarys et al., 1992; Davis and Blanksby, 1977; Elliott and Armour, 1988; Feltner, 1994; Feltner and Nelson, 1996; Feltner and Taylor, 1997; Stirn and Strojnik, 2006; Van der Wende, 2005; Whiting et al., 1985), but studies that include opposition (goalkeeper and/or defenders) are rare. Likewise, water polo related studies that look at the relationship between throwing velocity and the strength of the upper body are scarce (cf. Bloomfield et al., 1990; McMaster et al., 1990). Considering the lack of studies that analyze throwing velocity in water polo by specific playing positions, as well as its relationship with anthropometric parameters, the purpose of the present study is three fold: (i)

to describe the physical structure of elite water polo players by specific playing positions; (ii) to access throwing velocity, by specific playing position, in different conditions (without a goalkeeper, with a goalkeeper and with previous displacement) and (iii) to observe the relationships between anthropometric indices and throwing velocity in the three tested conditions attending to playing positions.

Material and Methods

Nineteen injury free male water polo players of the Spanish National Team were studied. Subjects were grouped according to their specific playing positions: nine offensive wings, five center backs and five center forwards. Subjects and coaches were minutely informed about the experimental protocol procedures, which was approved by the Institutional Review Committee of the local University and carried out according to the Declaration of Helsinki.

For the anthropometric assessment, the guidelines proposed by the International Working Group of Kinanthropometry were followed (Ross and Marfell-Jones, 1991). The anthropometric variables chosen were those considered as significant for sport performance in general and for water polo in particular (Aleksandrović et al., 2007; Bloomfield et al, 1990; Carter and Ackland, 1994; Platanou, 2005; Platanou and Geladas, 2006; Smith, 1998; Tsekouras et al. 2005).

Body mass, height, arm span, hand and foot length were accurately measured with a scale and a stadiometer (Seca, Germany). The humerus, wrist, femur, biacromial and biiliocristal breadths were determined with a paquimeter (Holtain Ltd., United Kingdom) and the arm (relaxed, and flexed and tensed), forearm, wrist, chest, waist, gluteus, tigh (upper and middle), calf and ankle girths were assessed through an inextensible fiber glass tape measure (Holtain Ltd., United Kingdom). In addition, five body composition parameters were assessed: the sum of the subscapular, triceps, supraspinale and abdominal skinfolds through a skinfold caliper (Holtain Ltd., United Kingdom), fat content (Yuhasz, 1974), muscle mass percentage (Martin et al., 1990), body mass index (BMI) and somatotype (Carter and Marfell-Jones, 1994). The front thigh, medial calf, bicipital, pectoral, axilar and iliac crest skinfolds were also assessed.

The experimental protocol for the assessment of throwing velocity was conducted in a short-course outdoor swimming pool with a mean depth of 2.0 m and the water temperature at 27.5º C. After a warm up of 15 min, centred in specific aspects of the throwing ability, the assessment of throwing velocity was evaluated using a radar with a register frequency of 100 Hz and with a sensitivity of 0.045 $m \cdot s^{-1}$ (Inc., Flat StalkerPro) placed after the goal post. Three series of two maximal intensity shoots, with a 3 min rest interval, were conducted using a standard water polo ball (Mikasa 6000): (i) from the penalty line (5.0 m) without a goalkeeper; (ii) from the penalty line with a goalkeeper and (iii) from the penalty

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line with previous displacement in perpendicular direction to the goal post. In each serie of two shoots, players were immediately informed of the accomplished results, being only the best trial chosen for data analyses.

Mean plus standard deviation computations for descriptive analysis were obtained for all variables (all data were checked for distribution normality and homogeneity with the Kolgomorov–Smirnov, Lilliefors and Levene tests). Pearson's correlation coefficients were also calculated. Due to the low number of subjects tested by specific playing position, comparison of means were developed through non parametric statistics, using the Friedman test for repeated measures as well as Kruskal-Wallis test for independent measures. A significance level of 5% was accepted.

Results

General physical and training background characteristics per specific playing position and for the total sample are presented in Table 1. It is possible to observe higher values of body mass, BMI, muscle mass of the center forwards compared to the wings, as well as higher values of foot length in the center backs compared with the wings. In addition, no significant difference was found between groups regarding breadths values.

In Table 1, it can also be observed that wings presented lower values of waist, gluteus, upper thigh and calf girths compared with center forwards. Complementarily, nonetheless the inexistence of differences between groups in the sum of skinfolds, significant differences were observed between center forwards and wings in the specific subescapular and axilar skinfolds.

When considering somatotype values, in Table 2 it is described the mean ± SD values of the three-number rating representing endomorphy, mesomorphy and ectomorphy components of water polo players by specific playing position. As it is possible to observe also in the somatochart presented in Figure 1, the somatotype of the wings is balanced mesomorph, the center backs and center forwards more endomorphs (classified as endo-mesomorphs). When referring to the all sample, indistinctively of specialized playing positions, it is possible to classify water polo players, in general, as balanced mesomorphs.

In Table 3, it is possible to observe the mean ± SD values corresponding to the throwing velocity by specific playing position in the three studied conditions, i.e., throwing without a goalkeeper, throwing with a goalkeeper and throwing with previous displacement. No differences were observed between specific playing positions in different studied conditions, as well as between the three conditions in each specific playing position. In addition, maximal grip value is presented, being observed a superiority of center backs in comparison to wings.

Table 4 presents the correlation coefficients of the anthropometric variables that significantly correlated with throwing velocity in the three tested conditions. Observing the correlation coefficient values by specific position for the three throwing conditions, it is possible to state that the

Table 1

Mean ± SD values of general physical and training background characteristics by specific playing position

	Wing (n=9)	Center back (n=5)	Center forward (n=5)	All players (n=19)
Age (yrs)	25.1±4.7	21.0±1.6	24.8±7.4	24.0±5.1
Training Experience (yrs)	12.9±2.8	10.2±1.1	12.8±4.9	12.2±3.2
Body Height (cm)	184.4±8.7	186.7±2.9	192.1±4.4	187.1±7.1
Body Mass (kg)	82.0±7.4*	91.4±10.2	102.3±11.0*	89.8±12.2
Arm span (cm)	192.2±7.7	192.8±6.2	203.0±7.1	195.2±8.3
Hand length (cm)	20.7±0.7	21.1±1.0	21.9±1.3	21.1±1.1
Foot length (cm)	27.3±1.2*	30.0±1.1*	28.1±1.1	28.2±1.7
Fat (%)	9.6±1.4	10.6±2.1	12.4±2.7	10.6±2.2
Body mass index	24.1±1.0*	26.3±3.4	27.7±2.3*	25.6±2.6
Muscle Mass (%)	48.5±4.1*	55.8±6.7	60.1±6.5*	53.5±7.3
Σ 4 skinfolds (mm)	31.4±6.3	37.8±10.9	45.0±10.9	36.6±10.2
Humerus breadth (cm)	7.1±0.4	7.0±1.1	7.7±0.3	7.2±0.7
Wrist breadth (cm)	6.0±0.3	6.0±0.3	6.5±0.5	6.2±0.4
Femur breadth (cm)	9.9±0.4	10.3±0.7	10.6±0.6	10.2±0.6
Biacromial breadth (cm)	43.1±2.7	44.5±1.0	46.7±3.1	44.4±2.8
Biiliocristal breadth (cm)	34.6±1.7	36.2±1.6	37.3±1.3	35.8±1.9
Arm relaxed girth (cm)	33.7±1.5	35.8±4.2	36.4±2.0	35.0±2.7
Arm flexed/tensed girth (cm)	36.3±1.4	38.3±3.8	38.7±2.2	37.5±2.5
Forearm girth (cm)	28.7±1.1	30.3±2.2	30.8±1.6	29.7±1.8
Wrist girth (cm)	17.4±0.9	17.6±0.9	18.3±0.7	17.7±0.9
Chest girth (cm)	103.6±4.0	106.3±7.7	111.8±6.4	106.5±6.4
Waist girth (cm)	83.4±2.2*	86.6±6.4	93.4±6.7*	86.9±6.3
Gluteus girth (cm)	98.0±3.6*	102.8±4.9	104.9±4.6*	101.1±5.1
Upper thigh girth (cm)	57.6±1.7*	61.4±3.7	63.7±3.9*	60.2±3.9
Middle thigh girth (cm)	56.9±12.57	55.9±4.91	57.9±3.92	56.9±8.90
Calf girth (cm)	36.1±1.5*	38.2±1.4	40.0±1.6*	37.7±2.2
Ankle girth (cm)	22.7±2.0	23.3±1.0	24.5±0.5	23.3±1.6
Triceps skinfold (mm)	8.6±2.7	9.6±0.8	11.7±1.9	9.7±2.5
Subscapular skinfold (mm)	10.0±1.9*	12.5±4.3	15.9±4.1*	12.2±3.9
Biceps skinfold (mm)	4.4±0.6	5.1±0.9	5.6±1.2	4.9±1.0
Pectoral skinfold (mm)	8.1±1.7	8.6±2.6	11.1±3.4	9.0±2.6
Axilar skinfold (mm)	9.0±1.9*	12.1±5.3	15.9±5.9*	11.6±4.9
Iliac Crest skinfold (mm)	14.0±3.9	17.7±10.4	20.3±10.9	16.6±8.0
Supraspinale skinfold (mm)	8.4±2.3	10.5±6.6	11.8±4.1	9.8±4.3
Abdominal skinfold (mm)	18.5±4.6	20.0±8.7	25.2±9.1	20.7±7.3
Front Thigh skinfold (mm)	13.1±4.1	14.1±2.1	17.7±5.3	14.6±4.3
Medial Calf skinfold	8.3±2.9	9.5±1.8	11.3±2.8	9.4±2.8

**Represents significant difference between groups ($p \leq 0.05$).*

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Table 2

Mean ± SD values of each somatotype component of water polo players by specific playing position

	Endomorphy	Mesomorphy	Ectomorphy
Wing (n=9)	2.53±0.62	5.01±1.20	2.40±0.68
Center back (n=5)	3.05±0.95	5.84±1.81	1.90±1.27
Center forward (n=5)	3.54±0.86	6.14±0.66	1.56±0.80
All players (n=19)	2.93±0.85	5.53±1.32	2.04±0.91

Table 3

Mean ± SD values of the throwing velocity (km.h^{-1}) by specific playing position in the three studied conditions: without goalkeeper, with goalkeeper and with previous displacement. Maximal grip (N) values are also preented.

	Without goalkeeper (km.h^{-1})	With goalkeeper (km.h^{-1})	With previous displacement (km.h^{-1})	Maximal Grip Strength (N)
Wing (n=9)	73.00±4.61	71.89±3.29	73.22±3.73	436.0±54.4*
Center back (n=5)	76.00±4.79	72.20±5.31	72.80±3.63	458.6±65.2
Center forward(n=5)	73.40±1.14	73.20±1.92	73.20±1.79	533.5±36.5*
All players (n=19)	73.89±4.07	72.31±3.50	73.10±3.14	467.6±65.5

**Represents significant difference between groups (p≤0.05).*

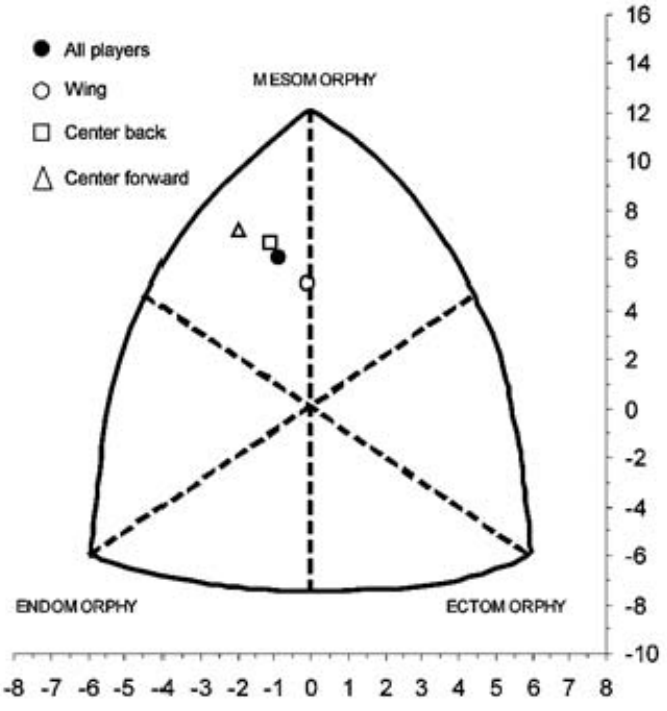

Figure 1.
Somatochart of water polo players by specific playing position

Table 4

Correlation coefficient values obtained between anthropometric variables and throwing velocity in the three tested conditions. Results are expressed by water polo specific playing position.

Specific Positions	Anthropometric characteristics	Throwing without goalkeeper	Throwing with goalkeeper	Dynamic shot
Wing (n=9)	Biacromial Breadth	r=0.68*	r=0.87**	r=0.59*
	Muscle Mass	r=-0.69*	ns	ns
	Ectomorphy	r=-0.65*	ns	ns
Center back (n=5)	Ankle girth	r=0.93*	ns	r=0.81*
	Femur Breadth	r=0.91*	r=0.89*	r=0.96*
	Pectoral skinfold	r=0.83*	r=0.81*	r=0.90*
	Iliac Crest skinfold	r=0.84*	ns	r=0.90*
	Hand length	r=0.93*	ns	r=0.71*
	Forearm girth	ns	r=0.92*	r=0.89*
	Wrist girth	r=0.85*	r=0.95*	r=0.94*
	Gluteus girth	ns	r=0.95*	r=0.94*
	Thigh girth med girth	ns	r=0.91*	ns
	Mesomorphy	ns	r=0.92*	r=0.96**
Center forward (n=5)	BMI	ns	r=0.90*	ns
	Triceps skinfold	ns	r=0.91*	ns
	Subescapular skinfold	ns	r=0.97**	ns
	Axilar skinfold	ns	r=0.97**	ns
	Iliac Crest skinfold	ns	r=0.96*	ns
	Supraespinale skinfold	ns	r=0.95*	ns
	Abdominal skinfold	ns	r=0.97**	ns
	Middle thigh skinfold	ns	r=0.92*	ns
	Waist girth	ns	r=0.97**	ns
	Gluteus girth	ns	r=0.95*	ns
	Σ 4 Skinfolds	ns	r=0.98**	ns
	Fat (%)	ns	r=0.97**	ns
	Endomorphy	ns	r=0.95*	ns
	Muscle Mass	ns	r=-0.94*	ns
All players (n=19)	BMI	ns	r=0.48*	ns
	Axilar skinfold	ns	r=0.46*	ns
	Iliac Crest skinfold	ns	r=0.49*	r=0.43*
	Supraespinale skinfold	ns	r=0.46*	r=0.48*
	Abdominal skinfold	ns	r=0.47*	r=0.43*
	Arm girth relaxed girth	ns	r=0.47*	ns
	Arm girth flexed and tensed girth	ns	r=0.48*	ns
	Femur Breadth	r=0.50*	r=0.57*	ns
	Biacromial Breadth	ns	r=0.53*	ns
	Acromiale-Radiale length	r=0.51*	ns	ns
	Mesomorphy	ns	r=0.52*	ns
	Grip Max	ns	r=0.50*	ns

**, ** Represents a significance for p≤0.05 and p≤0.001, respectively. ns, represents the non-existence of significance.*

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number of significant relationships for the center backs and center forwards rather than for the wings. Additionally, center forwards only presented significant correlations between anthropometric parameters and throwing velocity in throwing with a goalkeeper condition. When the total sample was analysed, a superior number of relationships between the studied parameters in throwing with a goalkeeper was observed.

Discussion

Water polo is an aquatic sport that requires a variety of physical and technical abilities that are specific of each playing position (Smith, 1998; Tan et al., 2009). Accepting that effective throwing seems to be dependent on anthropometric, strength and technical parameters, and that water polo related studies conducted by playing position role are scarce, the objective was to observe the influence of the subjects' anthropometric indices in their throwing velocity attending to their specific playing positions. A maximal grip strength related test was also conducted. Complementarily, three different throwing conditions were studied, trying to observe possible differences in the throwing velocity due to the presence/absence of a goalkeeper, and starting from a static position vs previous displacement. As a goalkeeper rarely shoot the ball during the game (Smith, 1998), they were not involved in the anthropometric characterization and throwing velocity assessment.

First of all, a tendency for higher anthropometric values of the center forwards compared to other players, the differences being more evident with the wings. This seems to be explained by the characteristics of the game, since body-to-body struggle with the opponent to gain an effective position next to the opponents goal is a constant objective in the center forwards attack strategies (Smith, 1998; Platanou and Geladas, 2006; Tan et al., 2009). Center forwards also presented higher values of maximal grip in comparison with the wings. Thus, better-adequate anthropometric parameters, as well as a higher level of strength, seem to be very important in playing positions in which players must face their opponents, through blocking, screening and pushing (Smith, 1998 Tsekouras et al., 2005).

Although some studies have already characterized the anthropometrics of male water polo players, few of them took into consideration the player's position. Drinkwater and Mazza (1994) as well as Platanou and Geladas (2006) also found that the center forwards (and the center backs) were taller and had greater body mass than the wings (the mean values are similar to our results); Tan et al. (2009) results corroborates our data but for female water polo players. Drinkwater and Mazza (1994) did not observe differences between specific positions in the sum of six skinfolds, percentage of muscle mass and

muscle/skeletal mass ratio. Smith (1998) also reported no differences in muscle mass between specific positions. The differences between centers and wings are reinforced by the obtained girth and breath values; in fact, higher values of girths and breaths seem to indicate a more adequate morphotype for holding the position against the pressure of the opponent, and to receive and protect the ball with more effectiveness, which are typical functions of the centers. Wings, although participating actively in the offensive and defensive process (Platanou and Geladas, 2006), play in the lateral paths, being more dynamic and do not get involved so often in intense struggle against the defenders (Smith, 1998; Tan et al., 2009). These facts are in agreement with the results obtained by Mazza et al. (1994).

Regarding the water polo players' somatotype, it was observed that the wings are balanced mesomorphs, and the center backs and center forwards endo-mesomorphs, which is in agreement with the literature (Pavicic et al., 2000; Carter and Marfell-Jones, 1994). The predominance of the mesomorphy and endomorphy components for all water polo players was previously described (Carter and Marfell-Jones, 1994; Platanou and Nikolopoulos, 2003), even for female players (Vramenti and Platanou, 2008).

Secondly, no significant differences between specific playing positions regarding the mean values of throwing velocity were observed. The highest values, although without statistical meaning, were obtained by the center backs in the throwing without a goalkeeper situation. When a tactical situation was included (the presence of a goalkeeper), a tendency for lower velocities in throwing movement was observed comparatively with the absence of opposition, which is in line with previous findings (Van der Wende, 2005). In addition, in throwing with a goalkeeper condition, the center forward presents a tendency for higher throwing velocity, which seems to be justified by the similitude of this testing situation with the normal shoot at goal in training and during competition conditions. In fact, the centers usually aim at the goal in the presence of the defenders and/or the goalkeeper, and nonetheless the importance of the precision of throwing (cf. Van der Wende, 2005), they are obliged to be fast and powerful. Under the last throwing situation, surprisingly, the observed values were not higher than the previous tested condition. This fact seems to be explained by the player's change of movement direction, from horizontal to vertical, which confirms that throwing after previous displacement is not a single kinetic chain but a complex movement. There are studies that analyzed throwing velocity by specific positions, but results were presented for the total sample, and different testing methodologies were employed (cf. Bloomfield et al, 1990; Davis and Blanksby, 1977; Elliott and Armour, 1988; Feltner and Nelson, 1996; Triplett et al., 1991; Van der

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Wende, 2005; Whiting et al., 1985), being difficult to compare with the present data.

Additionally, several high relationships were observed, by specific position, between the three throwing conditions and some anthropometric characteristics. A higher number of significant relationships for the center backs and center fowards rather than for the wings was found, which proves that throwing velocity of the wings depends more on other variables than their anthropometric characteristics (e.g. coordination; cf. Garbolewski and Starosta, 2002). Additionally, center forwards only presented significant correlations between the above-referred parameters in throwing with a goalkeeper condition, and, when the total sample was analysed, it was in this throwing situation that a higher number of relationships was observed. This fact shows the influence of the selected anthropometric variables in the throwing velocity final results, proving that players with better physical characteristics, particularly breaths, girths and, even, skinfolds, are also the ones who throw faster. This is in accordance with McCluskey et al. (2010) who observed the anthropometric variables indicative of strength, such as body weight, calf and upper arm girths, were associated with throwing velocity. Van den Tillaar (2004) also found positive relationships between general physical characteristics (height and weight) of handball players and their throwing velocity. In the present study, although no significant correlations were found between those specific variables, positive relationships were obtained with BMI, confirming that body size has a significant influence on throwing velocity in water polo. Complementarily, other significant observations were made: (1) the positive correlations of throwing velocity (in throwing with a goalkeeper condition) with the girths, skinfolds and maximal grip, showing that muscle mass and strength levels are other component that influence the ability to throw fast (in line with data from Van der Wende, 2005, and McCluskey et al., 2010); (2) Femur breadth correlated positively with throwing velocity, in throwing with a goalkeeper and throwing without a goalkeeper, what can be related to the importance of the trunk in stabilizing the lower body during the shot, as breadths can be identified or associated with higher levels of strength (Davis and Blanksby, 1977; Elliott and Armour, 1988); (3) The dependence of throwing velocity on biacromial breadth was confirmed, with particular relevance to the wings, particularly in the rotation of the trunk and shoulders during the throw, as highlighted before (Elliott and Armour, 1988; Van der Wende, 2005); (4) The different length variables studied were not correlated with throwing velocity, as suggested before (Bloomfield et al. 1990; Van der Wende, 2005).

Conclusions

As water polo is a physically demanding sport, it is evident that players require well-developed

physical capabilities to cope with the intense nature of the discipline. From an anthropometric point of view, it was concluded that players differ from each other in accordance with their playing position. The center forwards and the wings are the most diversified groups. However, despite those physical differences and the several high relationships between anthropometric characteristics and throwing velocity, no significant differences were observed between the different specific positions in throwing velocity. In addition, the similar throwing velocities values reached in the three throwing conditions imply that it is quite similar to throw with or without opposition, and with or without previous displacement.

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