Relationship Between Characteristics of Water Polo Players and Efficacy Indices

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Abstract

Alcaraz, PE, Abraldes, JA, Ferragut, C, Vila, H, Rodríguez, N, and Argudo, FM. Relationship between characteristics of water polo players and efficacy indices. *J Strength Cond Res* 26(7): 1852–1857, 2012–The aim of this study was to define and examine the relationships between the anthropometrical characteristics, maximum isometric grip strength, and competition throwing velocities and efficacy indices in high-level water polo player. Eleven elite trained male water polo players participated in this study. During preseason training, the following measures were taken: standard anthropometry (height, body mass, arm spam, skinfolds, body girths, and skeletal breadths) and grip strength. During official European Competitions ($n = 7$), efficacy indices (offensives: shot definition, resolution, precision, blocked and defensives: shot resolution when defending and shots stopped when defending), average and maximum throwing velocities from all the participants by zones and in some offensive tactical phases (even, counterattacks and power play) were also determined. Throwing velocities were different ($p \leq 0.05$) between some of the offensive tactical phases (even = 17.9 ± 2.4 vs. power play = 16.7 ± 2.6 $m \cdot s^{-1}$). In addition, significant correlations were found between competitive throwing velocities and different offensive efficacy indices. We concluded that there were significant correlations between conditioning and performance variables with anthropometrical characteristics and offensive tactical indices (blocked shots received and shot precision). Coaches should pay attention to these indices for the development of performance throughout the season.

Key Words physical fitness, anthropometry, championships, tactical analysis

Introduction

Water polo is a very stressful body-contact team sport that combines high-intensity short duration efforts such as swimming at maximum speed, elevation of the body from the water, and throwing, with rest or low-intensity actions (29). In addition, players need considerable strength to hit, block, and push other players during game play (27,32). For these reasons, the basic characteristics of the elite water polo player includes high levels of strength, swimming speed and lean body mass, and specific technical and tactical capabilities (1,17,23).

Although water polo requires high levels of physical fitness (22,30), throwing velocity is considered to be one of the most important aspects of performance (27,32). The extent of throwing speed will depend on the muscle-skeletal strength added to coordinating factors between body segments (lower limbs, body and upper limbs) and player technique (16). Consequently, there are many studies that have analyzed the biomechanical factors of water polo shot (5–7,9,21,28,32,33). Furthermore, accuracy and throwing velocity are 2 crucial factors for the efficacy of the throw (24). Nevertheless, studies that have included tactical situations when examining throwing velocities are scarce (6,32).

Anthropometry is another key aspect in elite water polo players, and this characteristic is developing continuously in sport (25). In fact, in water polo, Lozovina and Pavicicet (17) have noted anthropometrical changes across generations. In the last decade, there are some studies that have analyzed the anthropometric characteristics of elite male water polo players (1,4,11,23,31). However, studies that analyze the anthropometric characteristics of male water polo players in the last 5 years are again scarce (1,31).

In summary, physical (strength, power, throwing velocity) and anthropometrical factors are important for determining the outcomes in water polo. However, each of these variables has been defined in different studies in isolation. So, this is insufficient when it comes to describing the whole profile of elite water polo players. In addition, Hughes and Bartlett (12,13) explain that greater emphasis should be placed on the notation analysis for increasing performance

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from a biomechanical and physical point of view. Actually, it has been demonstrated that tactical awareness could be more decisive than physical aspects when the aim is detection of talent and early development of elite water polo players (8). Even, significant differences have been found in some efficacy indices between men's winning and loosing water polo teams (3) and for different competition levels (18,19). Some of these parameters are the offensive tactical phases: *even*, *counterattack*, and *power play*.

Thus, this study had 2 aims: The first was to define the anthropometrical characteristics, maximum isometric grip strength, competition throwing velocities (both by zones, and by the different offensive tactical phases), and the efficacy indices in high-level competition. The second was to determine the relationships or differences between the variables mentioned above in elite male water polo players.

Methods

Experimental Approach to the Problem

The study was developed in 2 phases. The training month before (precompetitive phase) and during the 2008 European Championship (competitive phase). In the precompetitive phase, standard anthropometry (height, body mass, arm span, skinfolds, body girths, and skeletal breadths) and grip strength were assessed. In the competitive phase, efficacy indices, and average and maximum throwing velocities from all the participants in the complete championship were recorded.

Subjects

Eleven elite trained male water polo players (age = 26.9 ± 4.5 years; height = 187.7 ± 7.4 cm; weight = 94.9 ± 12.5 kg; body mass index [BMI] = 26.9 ± 2.5 points; and grip strength = 48.7 ± 7.8 kilogram force [kgf]) were recruited from the Spanish water polo team (field players only). The participants read and signed statements of informed consent before participation in the study, and approval for the study was given by the Human Subjects Ethics Committee of the Catholic University San Antonio. For the 2008 Men's European water Polo Championship records, formal authorization from the Spanish Royal Swimming Federation and the Ligue Européenne de Natation (LEN) were obtained.

Anthropometry

The protocols of the International Society for the Advancement of Kinanthropometry (14) were used to determine the anthropometric profile of the water polo players. The subjects were measured in the early morning during a single session. Unilateral measurements were taken on the right side of the body. The participants wore 'light clothing' but no shoes. Physical characteristics were measured in the following order: height, body mass, arm span, skinfolds, body girths, and skeletal breadths. The anthropometric program included 25 measurements. Height and weight measurements were made on a leveled platform scale (Seca, Hamburg, Germany) with an accuracy of 0.01 kg and 0.001 m, respectively. Eight skinfolds (triceps, subscapular, biceps, axillary, abdominal, iliac crest, suprailiac, front thigh, and medial shank) were measured by means of a Holtain Skinfold Calliper (Holtain, Crymych, United Kingdom) with 10 $g \cdot mm^{-2}$ constant pressure. Ten limb/body girths (arm relaxed, arm flexed and twitched, forearm, wrist, chest, waist, gluteus, thigh, shank, and ankle) were measured using a diameter steel tape (Lufkin Executive Thinline, Lufkin, TX, USA), and 5 skeletal breadths (biacromial, biepicondylar-humerus, biepicondylar-femur, biiliocristal, and bistyloid) were measured using an anthropometer (GPM, Zurich, Switzerland).

Double measures for each of 25 anthropometric dimensions (triple measures for skinfolds) were obtained by 1 accredited levels 2 and 3 accredited level 1 ISAK anthropometrists. The technical error of measurement was <2% for all skinfolds and <1% for all bone breadths and body girths.

Other derived variables included the following: (a) the BMI was calculated as weight (kilograms) divided by height^2 (meters); (b) percentage of body fat was estimated from the measurements of skinfold thickness using the method described by Jackson et al. (15); and (c) fat-free mass (kilograms) using the method described by Martin et al. (21).

Maximum Isometric Grip Strength

Maximum isometric hand-grip strength was recorded using a handheld hand-grip dynamometer (TKK 5401, Tokyo, Japan) to the nearest 0.1 kgf. The participants were familiarized with the dynamometer and performed 3 warm-up repetitions on the same day of the testing, with 3 minutes of rest. After that, the players performed 2 repetitions at maximum intensity with the dominant hand, with 3 minutes of rest. They carried out the test from 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 flexion. The best trial was used for further analysis.

Championship Throwing Velocities

To assess ball velocity, a radar gun (StalkerPro Inc., Plano, TX, USA) with a record data frequency of 33 Hz was used. The radar was placed 10 m behind the goal post and aligned with the penalty line (Figure 1). Usually, it is recommended that the throwing velocities registered by radar should be done from a frontal plane. However, a recent study has validated the radar vs. a photogrammetric method with a high-speed video camera from different zones of the pool (player $\theta = 20°$ from the radar gun) with coefficients correlations of $r = 0.97$ and $p = 0.001$ (10). We analyzed all the shots carried out in the 2008 Men's European Water Polo Championships by the male Spanish team (163 throws in 7 matches). Individual average and maximum throwing velocities were classified by different zones (Figure 1): *zone* 0 was defined by the area between the goal and the 1/2 pool line; *zone* 1 was defined by the area between the goal and the first 2 m; *zone* 2 was defined by the area between 2 and 5 m from the goal; and *zone* 3 was defined by the area between the 5 m and the 1/2

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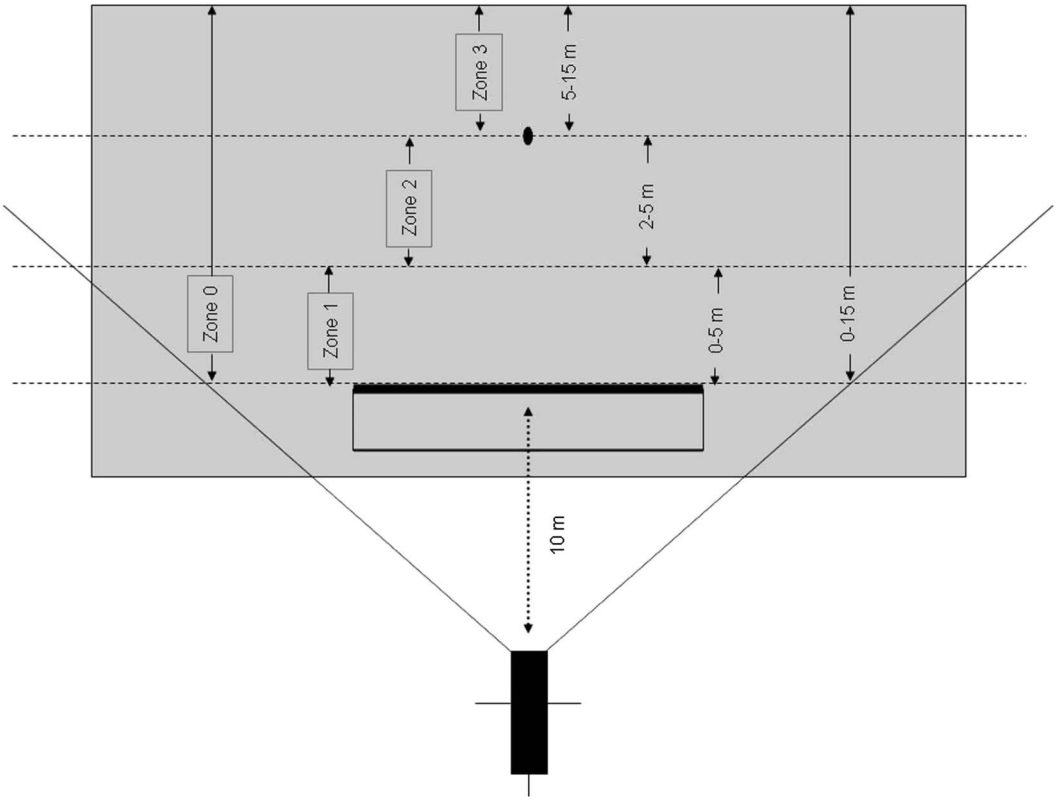

Figure 1. Schematic representation of the radar position and the different pool zones established when recording the competition throwing velocities and the tactical actions.

pool line from the goal. The zone from 0 to 2 m (off-side area) from the goal was not selected for the analysis because there were very few throws from this zone for all the players. In *zone* 0, a minimum of 5 throws and a maximum of 30 by each player were assessed (average = 14.8 ± 8.9 shots); *zone* 2 had min = 2, max = 13, average = 7.4 ± 4.0 shots, and zone 3 had min = 1, max = 17, average = 8.2 ± 6.2 shots.

Efficacy Indices

The analysis of the tactical variables was based on an observational methodology from previous research (26). The selected variables were determined by a group of expert coaches and researchers. The matches were analyzed through systematic observation by 2 experienced observers, trained using the methodology described by Anguera and Santoyo (2). Additionally, the interrater reliability of 2 separate observations was calculated to guarantee the quality of the observation system, with a subsequent reliability index of 0.95 being observed (intraclass correlation coefficient and kappa index).

Furthermore, throwing velocities were also analyzed in relation to the following offensive tactical phases (i.e., *even*, *counterattacks*, and *power play*). In particular, *even* situations are characterized by a number of offensive players relative to the ball position, which is never larger than that of the defense; *counterattacks* refer to playing situations in which the number of offensive players relative to the ball position is larger than that of the defense; *power play* actions are played further to an exclusion foul of a defensive player who has to go out of the court for 20 seconds of clock time (18,19).

The variables recorded have been divided into offensives (i.e., when the Spanish team had possession of the ball) and defensives (i.e., when the Spanish team was not in possession of the ball). In addition, we subdivided the offensives into 4 categories. These were (a) percentage of shot definition (PSD) = sum of goals × 100/sum of throws performed; (b) percentage of shot resolution (PSR) = (sum of goals × 100/sum of throws performed − [sum of throws went out + sum of throws blocked + sum of throws went post]); (c) percentage of shot precision (PSP) = (sum of throws performed − [sum of throws went out + sum of throws blocked + sum of throws went post]) × 100/sum of throws performed; and (d) percentage of blocked shots received (PBSR) = sum of blocked received × 100/sum of throws performed. The defensive values were subdivided into 2 categories. In this case, they were (a) PSR when defending

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Table 1. Upper and lower limb girths and breadths ($n = 11$).*

Upper limb girths (cm)	Upper arm (relaxed)	36.2 ± 2.8
	Upper arm (flexed)	38.7 ± 2.6
	Forearm	30.6 ± 1.7
	Wrist	18.0 ± 0.7
	Mesoesternal	110.3 ± 5.4
Lower limb girths (cm)	Waist	89.5 ± 6.6
	Gluteal	103.9 ± 4.3
	Upper thigh	62.0 ± 3.9
	Medial thigh	56.7 ± 3.6
	Shank	38.2 ± 2.1
	Ankle	23.8 ± 1.6
Upper limb breadths (cm)	Biacromial	44.3 ± 3.7
	Transverse chest	25.8 ± 1.9
	Bistyloid	6.4 ± 0.3
	Biepicondylar	7.56 ± 1.1
Lower limb breadths (cm)	Biiliocristal	35.1 ± 4.2
	Femur	10.4 ± 0.7

*Values are given as mean ± *SD*.

(PSRD) = throws detain × 100/total throws; (b) percentage of shots stopped when defending (PSSD) = throws detain × 100/total throws − (sum of throws went out + sum of throws blocked + sum of throws went post). Furthermore, the efficacy indices were classified by zones (0, 2, and 3; Figure 1).

Statistical Analyses

Mean and *SD* scores were calculated for all the variables measured in the study. Significant differences between efficacy indices by zones and throwing velocities between the offensive tactical phases were analyzed using 1-way analyses of variance. When significant differences were obtained, Tukey's post hoc test was applied over zones and offensive tactical phases. Pearson product-moment correlation coefficients (r) were used to determine the relationships of all anthropometric measures and tactical variables with throwing velocities and grip strength. Effect sizes were calculated using Cohen's d and were reported when appropriate (small effect size; $d = 0.2$–0.3). The $p \leq 0.05$ criterion was used for establishing statistical significance.

Results

Table 1 summarizes the mean values (±*SD*s) of the upper and lower girths and breadths of the players. The body composition was as follows: muscular = 48.6 ± 2.2%; bone = 15.7 ± 0.8%; fat = 11.6 ± 2.4%; sum of 4 skinfods (triceps, subscapular, suprailiac, and abdominal) = 67.7 ± 22.2 mm).

Table 2 describes the maximum and average throwing velocities (by zones and by offensive tactical phases) of the Spanish national team at the 2008 Men's European Water Polo Championships. Regarding the maximum competition velocities by zones, the only significant differences found were between *zone* 0 and *zone* 2 ($p = 0.027$). Also, significant differences were found between average velocities from *zone* 2 and *zone* 3 ($p = 0.001$). Concerning the average throwing velocities by offensive tactical phases, significant differences ($p = 0.043$) were found between *even* and *power play* situations.

The efficacy indices shown in Table 3 indicate that there are differences between zones; however, these differences were not statistically significant. As expected, in the offensive variables, the percentages are higher when the players are nearer the goal. However, in the defensive variables, they are lower when the players are farther from the goal.

Relationships between physical fitness and anthropometric characteristics and efficacy indices were also analyzed, and different significant correlations were found. With regard to grip strength, significant correlations were found with different body

Table 2. Average and maximum (average of the fastest throws by each of the 11 players) competition throwing velocities by zones ($n = 11$) and by the different offensive tactical phases.*

Throw type	Velocity ($m \cdot s^{-1}$)
Competition maximum throw from zone 0	20.4 ± 1.5†
Competition average throw from zone 0	17.0 ± 1.4
Competition maximum throw from zone 2	18.6 ± 2.3
Competition average throw from zone 2	16.1 ± 1.6
Competition maximum throw from zone 3	19.9 ± 2.2
Competition average throw from zone 3	18.1 ± 1.6†
Average throw in the even situation	17.9 ± 2.4†
Average throw in the counterattack situation	17.0 ± 2.6
Average throw in the power play situation	16.7 ± 2.6

*Values are given as mean ± *SD*.
†Significantly different ($p \leq 0.05$) from zone 2 or from the power play situation.

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Table 3. Efficacy indices in the different pool zones ($n = 11$).*†

	Offensives				Defensives	
	PSD	PSR	PSP	PBSR	PSRD	PSSD
Zone 0	40.3 ± 12.8	57.3 ± 13.4	70.7 ± 16.5	13.1 ± 7.8	30.4 ± 11.9	42.7 ± 13.4
Zone 2	52.2 ± 0.7	64.0 ± 17.1	81.5 ± 20.6	13.1 ± 4.6	32.2 ± 14.9	39.6 ± 12.9
Zone 3	35.0 ± 12.5	58.6 ± 25.5	60.6 ± 18.8	22.1 ± 19.7	34.2 ± 18.5	55.7 ± 26.4

*PSD = percentage of shot definition; PSR = percentage of shot resolution; PSP = percentage of shot precision; PBSR = percentage of blocked shots received; PSRD = percentage of shot resolution when defending; PSSD = percentage of shots stopped when defending.

†Values are given as mean ± *SD*.

composition (muscular mass: $r = 0.69$, $p = 0.017$; bone mass: $r = 0.72$, $p = 0.011$), girth (mesosternal: $r = 0.65$, $p = 0.031$; gluteus: $r = 0.72$, $p = 0.013$; upper thigh: $r = 0.70$, $p = 0.016$; medial thigh: $r = 0.61$, $p = 0.047$), and breadth (biacromial: $r = 0.67$, $p = 0.024$; femur: $r = 0.76$, $p = 0.007$) variables. Regarding the championship throwing velocities, significant correlations were found between these velocities and different offensive efficacy indices ($V_{0average}$ vs. PBSR: $r = 0.66$, $p = 0.05$; $V_{2average}$ vs. PSP: $r = -0.68$, $p = 0.03$; V_{3max} vs. PBSR: $r = -0.88$, $p = 0.049$).

Discussion

To our knowledge, this study is the first to concurrently define and investigate the relationships between anthropometry, grip strength, competitive throwing velocities, and tactical characteristics of elite male water polo players. One of the major finding of the present research was that throwing velocities are different between some of the offensive tactical phases. A second major finding was that grip strength has a strong correlation with body composition and different body girths and skeletal breadths, whereas competition throwing velocities significantly correlate with different efficacy indices in highly skilled water polo players.

Although, some authors (3,18–20) considered tactical aspects of elite water polo, especially in relation to playing situations involving an *even* or *uneven* (i.e., *power play* and *counterattack*) numbers of players. To our knowledge, this is the first study that compares the throwing velocity between the different offensive tactical phases. In this study, the *even* actions were characterized by a high throwing velocity (17.9 ± 2.4 m·s^{-1}) vs. the lower velocity (16.7 ± 2.6 m·s^{-1}) in the *power play* situation, suggesting that the players have more time for preparing the shot, and this throw is faster and, consequently, more dangerous. For this reason, the higher occurrence of goals scored by the winning teams during *even* actions (20) could be explained by the higher velocity reached by the players in the situation mentioned.

Competition throwing velocities significantly correlated with some offensive efficacy indices. Blocks received significantly and inversely correlated with average throwing velocity from *zone* 0 and maximum throwing velocity from *zone* 3. Although we have not found research that correlated efficacy indices with high-level water polo throwing velocities, again, we can deduce that the faster the ball is, the lower is the goalkeeper and defender reaction time to block the throw. From *zone* 2, an inverse and significant correlation was found between shot precision and average throwing velocity. It should be noted that from *zone* 2 throwing velocities are typically lower, this occurs probably because the players have the aim of being more accurate.

Regarding the efficacy indices, the highest values were registered at *zone* 2, for both offensive and defensive situations, although these differences were not significant. It is clear that *zone* 2 is the higher efficacy zone (PSD, PSR, PSP). The key actions relating to *losing* a match (i.e., PBSR, PSRD, PSSD) took place mostly in *zone* 3. The data could not be compared, because other studies that relate the efficacy indices in water polo were not found. Concerning the significant correlations between physical characteristics and anthropometry and tactical indices, biacromial and biepicondylar-femur breadth showed a positive and significant correlation with hand-grip strength. We only found significant correlations between mesoesternal girths with throwing velocity from *zone* 3. Therefore, the anthropometric characteristics do not seem to be much representative of competition throwing velocities.

Practical Applications

After studying the physical and anthropometric characteristics and efficacy indices and correlating them in highly skilled water polo players, we conclude that (a) throwing velocities in the *even* situation is higher than in the *power play* situation; (b) there is a strong and significant correlation between conditioning and performance factors with anthropometrical and tactical characteristics; (c) grip strength is significantly related to some anthropometrical variables of lower and upper limbs; (d) offensive tactical aspects (blocked received and shot precision) are related to

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throwing velocities; and (e) in the zone close to the goal, precision and accuracy seem to be more important than throwing velocity is. On summarizing, this study is applied to training because it shows a lot of different determinant variables related to each other in high-level water polo players. In this sense, coaches should pay attention to these indices for the development of performance throughout the season.

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