Throwing Velocities, Anthropometric Characteristics, and Efficacy Indices of Women's European Water Polo Subchampions

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Abstract

Alcaraz, PE, Abraldes, AJ, Ferragut, C, Rodríguez, N, Argudo, FM, and Vila, H. Throwing velocities, anthropometric characteristics, and efficacy indices of Women's European Water Polo Subchampions. *J Strength Cond Res* 25(11): 3051–3058, 2011—Water polo is a team sport characterized by a high-intensity, intermittent activity, where technical and tactical aspect are of a great importance. For that reason, the main aim of this study was to define the anthropometrical characteristics, maximum isometric grip strength, training and competition throwing velocities, and the efficacy indices in female high-level water polo players. A second purpose was to examine the differences between the throwing velocities in training vs. European championships in the water polo female national team. Ten elite trained female water polo players participated in this study. Before the competitive phase of their season, the following measures were taken: standard anthropometry, static and dynamic training throwing velocities, and hand-grip dynamometry. In the competitive phase, efficacy indices, average and maximum throwing velocities from all the participants were also determined. Significant differences ($p \leq 0.05$) were found between different training situations and different competitive throwing velocities. We concluded that elite female water polo players modify their throwing velocity depending if the throw is performed during training or competitive situation.

Key Words physical fitness, anthropometry, championships, tactical analysis

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25(11)/3051–3058

Journal of Strength and Conditioning Research

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 (31). In addition, players need considerable strength to hit, block, push, and hold other players during game play (28,33). For these reasons, the basic characteristics of elite water polo players include high levels of strength, swimming speed, lean body mass, and specific technical and tactical capabilities (3,19,24).

Although water polo requires high levels of physical fitness (23,32), throwing velocity is considered to be one of the most important aspects of performance (28,33). The extent of throwing speed depends on the muscle–skeletal strength added to coordinating factors between body segments (lower limbs, body and upper limbs) and player technique (18). In this sense, there are many studies that have analyzed the biomechanical factors of water polo shot (6,8,10,12,22,30,33,34). It seems that accuracy and throwing velocity are 2 crucial factors for the efficacy of the throw (25). To our knowledge, only one study has been found that investigated the throwing velocity of elite female water polo players.

Knowledge of the anthropometric characteristics of elite water polo players can be used by coaches in appropriate selection and preparation methods, because anthropometry is another key aspect in elite water polo players, and this characteristic is developing continuously in sport (26). In fact, in water polo, Lozovina et al. (19) have noticed anthropometrical changes across generations. In this sense, studies that analyze the current anthropometric characteristics of female water polo players are again scarce (21,32).

In summary, physical (strength, power, throwing velocity) and anthropometrical factors are important for determining outcomes in water polo. However, Hughes and Bartlett (15,16) explain that greater emphasis should be placed on the notation

TABLE 1. General characteristics of the sample (n = 10).*†

Age (y)	Height (cm)	Body mass (kg)	BMI ($kg \cdot m^{-2}$)	Training experience (y)	Reach (cm)	Hand-grip dynamometry (kgf)
23.5 ± 2.1	171.0 ± 6.5	64.2 ± 5.2	22.0 ± 1.6	8.9 ± 2.7	176.6 ± 7.4	27.4 ± 7.6

*BMI = body mass index (BMI = body mass·height^{-2}).
†Values are given as mean ± *SD*.

analysis for increasing performance 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 detecting talent and early development of elite water polo players (11). Even, significant differences have been found in some efficacy indices between men's winning or losing water polo teams (5) and for different competition levels (20).

Considering that the basic characteristics of elite water polo players would assist coaches in profiling players and evaluating adaptations to training, the main aim of this study was to define the anthropometrical characteristics, maximum isometric hand-grip strength, training and competition throwing velocities, and the efficacy indices in high-level competition. A second purpose was to examine the differences between the throwing velocities in training vs. European championships in the women's national water polo team.

METHODS

Experimental Approach to the Problem

With the aim of studying the physical, anthropometrical, and tactical variables, a quasiexperimental, intrasubject cross-sectional study was carried out. The study was performed 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 spam, skinfolds, body girths, and skeletal breadths), static and dynamic training throwing velocities, and hand-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

Ten elite trained female water polo players (23.5 ± 2.1 years) were recruited from the Spanish water polo team (Table 1) (field

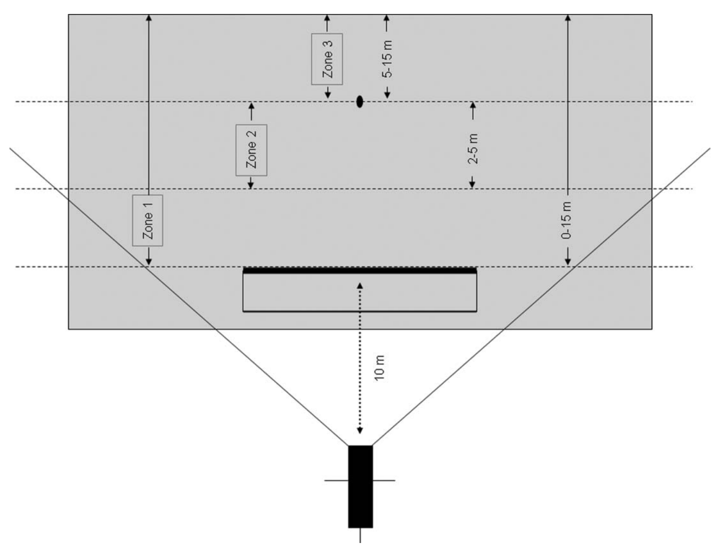

Figure 1. Schematic representation of the radar position and the different pool zones established when recording the competition throwing velocities and the tactical actions.

TABLE 2. Body composition (n = 10).*†

Gender	Muscular (%)	Bone (%)	Fat (%)	∑4 (mm)
♀	45.4 ± 2.5	16.5 ± 1.3	17.2 ± 2.6	71.5 ± 15.1

*∑4 = sum of 4 skinfolds (triceps, subscapular, suprailiac, and abdominal).
†Values are given as mean ± *SD*.

players only). These players won silver medals at the 2008 European Championship. 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 San Antonio Catholic University of Murcia. For the 2008 Women's European water Polo Championship records, formal authorization from the Spanish Royal Swimming Federation and the Ligue Européenne de Natation (LEN) were obtained.

Procedures

Anthropometry. International Society for the Advancement of Kinanthropometry (ISAK) protocols were used to determine the anthropometric profile of the water polo players. Subjects were measured in the early morning during a single measurement session. Unilateral measurements were taken on the right side of the body. Participants wore light clothing but not shoes. Physical characteristics were measured in the following order: height, body mass, arm span, skinfolds, body girths, and skeletal breadths. The anthropometric program included 30 measurements. Height and body mass 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 Holtain Skinfold Calliper (Holtain, Crymych, United Kingdom) with 10 $g \cdot mm^{-2}$ constant pressure. Ten limb and 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 one accredited level II and 3 accredited level I 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 (a) the body mass index, which was calculated as body mass (kg) divided by height^2 (m); (b) percentage of body fat was estimated from measurements of skinfold thickness using the method described by Jackson et al. (17); (c) fat-free mass (kg) using the method described by Martin et al. (22); and (d) somatotype, which was determined from selected anthropometric measures following the methods described by Carter et al. (7).

Maximum Isometric Hand-Grip Strength. Maximum isometric hand-grip strength was recorded using a handheld hand-grip dynamometer (TKK 5401, Tokyo, Japan) to the nearest 0.1 kilogram of force (kgf). The participants were familiarized with the dynamometer performing 3 warm-up repetitions the same day of the testing, with 3-minute rest. After that, the

Table 3. Upper and lower limb girths ($n = 10$).*†

	Upper limb girths (cm)					Lower limb girths (cm)					
Gender	AR	AF	FA	W	M	WA	G	UT	MT	S	A
♀	30.2 ± 1.9	30.7 ± 2.6	24.8 ± 1.1	15.3 ± 1.1	89.5 ± 3.2	70.9 ± 2.9	98.4 ± 5.5	57.4 ± 4.0	49.8 ± 2.0	33.7 ± 1.4	21.8 ± 0.8

*AR = arm relaxed; AF = arm flexed and twitched; FA = forearm; W = wrist; M = mesoesternal; WA = waist; G = gluteal; UT = upper thigh; MT = medial thigh; S = shank; A = ankle.
†Values are given as mean ± *SD*.

Table 4. Upper and lower limb breadths ($n = 10$) (mean ± *SD*).*

	Upper limb breadths (cm)				Lower limb breadths (cm)	
Gender	Biacromial	Bistyloid	Biepicondylar	Hand width	Bi-iliocristal	Femur
♀	35.5 ± 9.6	5.3 ± 0.3	6.4 ± 0.4	20.0 ± 1.0	33.3 ± 1.9	9.3 ± 0.6

*Values are given as mean ± *SD*.

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.

Throwing Velocities. Training throwing velocities: To assess specific strength in the participants, 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). The players were instructed to perform 6 maximal throws under 3 different conditions (2 shots in each condition) from the 5-m penalty line. The 3 conditions included the following: (a) no defender or goalkeeper; (b) goalkeeper only; (c) with 3 swimming strokes to the shooting line and with goalkeeper. After a 10-minute standardized warm-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 1 hand and their own technique. For each type of throw, each participant performed trials until 2 correct throws were recorded, up to a maximum of 3 sets of 3 consecutive throws. A 2- to 3-minute rest elapsed between sets of throws, and 20–30 seconds elapsed between 2 throws of the same set. The best shot was selected for the analysis. For motivation, players were immediately informed of their performance.

Championships throwing velocities: For the championships throwing velocities, the same position of the radar gun that in the training session was used. 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 coefficient correlations of $r = 0.97$ and $p = 0.000$ (2,13). We analyzed all the shots carried out in the championships by the female Spanish team (232 throws in 7 matches). Individual average and maximum throwing velocities were classified by different zones (Figure 1): Zone 1 was defined by the area between the goal and the half pool line; zone 2 was defined by the area between the 2 and 5 m from the goal; and zone 3 was defined by the area between the 5 m and the half pool line from the goal. In zone 1, a minimum of 3 throws and a maximum of 29 by each player were assessed (average = 13.3 ± 9.7 shots); in zone 2 (min = 1; max = 24; average = 6.6 ± 7.6 shots); and in zone 3 (min = 1; max = 16; average = 8.4 ± 5.2 shots).

Efficacy Indices

The analysis of the tactical variables was based on an observational methodology based upon previous research (14,27). 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 (4).

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). In addition, we subdivided the offensives into 4 categories. These were (a) percentage of shot definition (PSD) = sum of

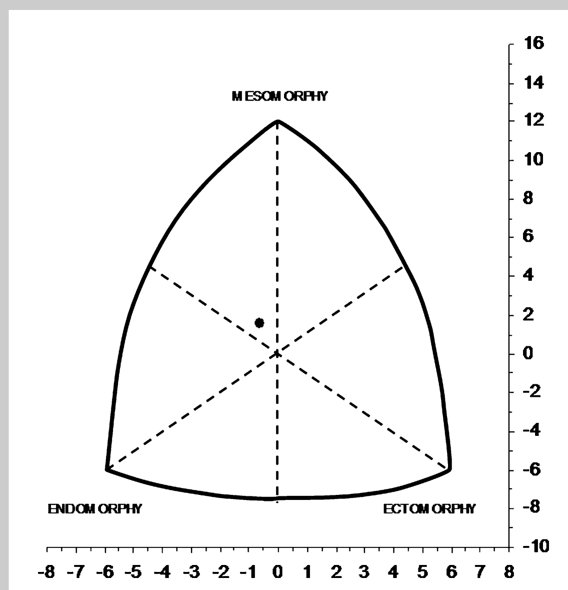

Figure 2. Somatotype of the national Spanish female water polo team.

Table 5. Average and maximum training and competition throwing velocities ($n = 10$).*†

Tv_1 ($m \cdot s^{-1}$)	Tv_2 ($m \cdot s^{-1}$)	Tv_3 ($m \cdot s^{-1}$)	Cv_{1max} ($m \cdot s^{-1}$)	Cv_{1aver} ($m \cdot s^{-1}$)	Cv_{2max} ($m \cdot s^{-1}$)	Cv_{2aver} ($m \cdot s^{-1}$)	Cv_{3max} ($m \cdot s^{-1}$)	Cv_{3aver} ($m \cdot s^{-1}$)
15.7 ± 1.6‡§	15.4 ± 1.2‡§	13.9 ± 5.3‡§	18.4 ± 3.3	14.6 ± 1.4	15.8 ± 3.4‡	14.1 ± 2.4	18.9 ± 3.0	15.5 ± 0.9

*Tv_1 = static training velocity from 5 m without the goalkeeper; Tv_2 = static training velocity from 5 m with the goalkeeper; Tv_3 = dynamic training velocity from 5 m with the goalkeeper; Cv_{1max} = competition maximum velocity from all positions; Cv_{1aver} = competition average velocity from all positions; Cv_{2max} = competition maximum velocity from zone 2 (~2–5 m from the goal); Cv_{2aver} = competition average velocity from zone 2; Cv_{3max} = competition maximum velocity from zone 3 (~5 m from the goal until the half pool line); Cv_{3aver} = competition average velocity from zone 3.
†Values are given as mean ± *SD*.
‡Significant differences from Cv_{1max}.
§Significant differences from Cv_{3max}.

throws scored × 100/sum of throws performed; (b) percentage of shot resolution (PSR) = (sum of throws scored × 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) percentage of shot resolution when defending (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 (1–3; Figure 1).

Statistical Analyses

Mean and *SD* scores were calculated for all the variables measured in the study. Significant differences between training or championships velocities, and efficacy indices by zones were analyzed using paired samples *t*-tests. 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). The $p \leq 0.05$ criterion was used for establishing statistical significance.

Results

Tables 2–4 summarize the mean values (±*SD*s) of the body composition, upper and lower girths, and breadths of all participants. Figure 2 presents the somatotype of the female Spanish water polo players.

Table 5 and Figure 3 present training maximum throwing velocities in the different training situations and describes the maximum and average throwing velocities (by zones) of the Spanish national team at the 2008 European Championships. There were no significant differences between the 3 training velocities in the different situations. Regarding the maximum competition velocities, only significant differences were found between zones 1 and 2 ($p = 0.026$). When comparing

Table 6. Efficacy indices in the different pool zones ($n = 10$).*†

	Offensives (%)				Defensives (%)	
Zone	PSD	PSR	PSP	PBSR	PSRD	PSSD
1	29.0 ± 21.0	40.8 ± 25.6	59.6 ± 25.4	7.5 ± 9.3	30.5 ± 9.8	59.2 ± 25.6
2	54.9 ± 34.0	60.5 ± 34.6	83.3 ± 23.7	5.7 ± 12.0	28.5 ± 23.7	39.5 ± 34.6
3	17.2 ± 13.0	33.0 ± 24.2	49.8 ± 16.5	8.6 ± 9.4	32.6 ± 16.5	67.0 ± 24.2

*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*.

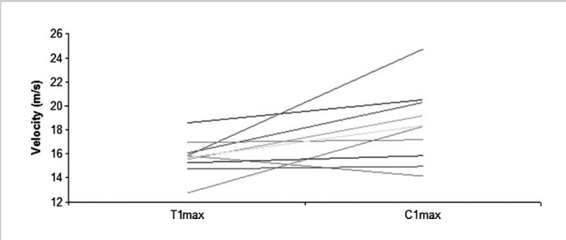

Figure 3. Spaghetti graph on training (situation 1) vs. competition throwing velocities (zone 1).

the competition velocities against the training one, significant differences were found between all the training throwing velocities with competition maximum velocity from zone 1.

The efficacy indices shown in Table 6 indicate that there are differences between zones, although these differences were not statistically significant. As expected, in the offensive variables, the percentages are higher when the players are nearer to the goal. However, in the defensive variables, they are lower when the players are further from the goal.

Discussion

To our knowledge, this study is the first to concurrently investigate anthropometry, hand-grip dynamometry, training and competitive throwing velocities and tactical characteristics of elite female water polo players and to compare the differences between the training and competition throwing velocities. The results demonstrated significant differences between training and competition throwing velocities in elite female water polo players.

Spanish water polo players showed mean maximum training throwing velocities of $\sim$15.7 $\pm$ 1.6 $m \cdot s^{-1}$. These velocities were slightly different between situations, but the differences were not significant. This finding is in accord with that of van der Wende (33), who did not show any differences in throwing velocity with or without a goalkeeper. The maximum throwing velocity reached in the training situation was greater than others reported with female water polo players. For example, female collegiate water polo players obtained average maximum throwing velocities of $\sim$11.6 $\pm$ 1.4 $m \cdot s^{-1}$ (29). These differences could be because of the different levels of the sample or the different methods used. Our sample consists of highly skilled players, who throw faster than the other players reported. It could be postulated that the higher the level of the players, the higher the velocity in the shot. In relation to championship maximum throwing velocities from all positions, these were significant different from those reached in the training situations. Unfortunately, no data have been found regarding this aspect in female elite water polo players. Only, one study has compared the throwing velocity differences in training vs. European championships in the water polo Spanish female national team (1). This study concluded that throwing velocity is similar when a water polo player performs a shot from the penalty line with the goalkeeper, independent of the situation (with or without the goalkeeper). However, when throwing velocities are compared from different dynamic positions, when the stress is higher than in the static position like the penalty, the differences are significant. Regarding the championship maximum throwing velocities, there were significant differences between zones 1 and 2. When the maximum and average throwing velocities are analyzed, it can be noticed that a loss of velocity is produced; this loss is >10% in zones 2 and 3 ($\sim$10.8 and 18.0%, respectively) and >20% in zone 1 ($\sim$20.6%). In this sense, the coach should place more attention on this aspect, because in water polo, the assumption is the faster the ball is thrown, the less time the goalkeeper has to deflect the ball thereby increasing the likelihood of scoring goals.

In water polo, the anthropometric characteristics of elite players have been defined (9,21,32). However, as noted, these characteristics are in constant evolution (19). It seems that 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 in male players (19). However, our study showed that height and body mass of Spanish female elite water polo players are different, when compared with recent data from the Australian Women's National Squad (height = 173.7 $\pm$ 5.5 cm; body mass = 74.6 $\pm$ 8.0 kg) (32). Conversely, these variables (height and body mass) are similar to those presented by Drinkwater et al. (9) in elite international-level female water polo from the 1991 World Championships (height = 171.3 $\pm$ 5.9 cm; body mass = 64.8 $\pm$ 7.2 kg). Similarly, when compared with recent data from the Scottish Women's National Squad (height = 168.7 $\pm$ 7.9 cm; body mass = 65.9 $\pm$ 6.1 kg) (21), the Spanish players were moderately taller ($\sim$1.3 cm), and weighed less ($\sim -$1.7 kg). Based on the 2009 World Championships classification, Spain and Australia teams present a similar level (eighth vs. sixth, respectively); in this sense, a direct cause–effect relationship cannot be established between body mass and match performance. In addition, it seems that anthropometrics characteristics in female water polo players are not related with the period (year) of the measurement or the level of the sample.

Regarding the efficacy indices, the highest values were registered at zone 2, for offensive situations, although these differences were not significant. It is clear that zone 2 is the higher efficacy zone (PSD, PSR, PSP), and this area presents the lowest number of defensive actions (PSRD, PSSD) The key actions relating to losing a match (i.e., PBSR, PSRD, PSSD) took place mostly in zone 3. These data could not been compared, because other studies that relate the efficacy indices in water polo were not found. Recently, one paper has been published in which the notational analysis has been included (20). But, unfortunately, the variables analyzed are different from those shown in our study. Lupo et al. (20) have demonstrated that the competition level has a relevant impact on the occurrence of technical and tactical indicators especially in relation to even, counterattack, and power play situations. Thus, notational analysis proved to be a valuable tool for better coaching through the interpretation of technical and tactical aspects of water polo in relation to its competition level. In this sense, more research is needed in relation to this topic.

Practical Applications

After studying the physical and anthropometric characteristics and efficacy indices in highly skilled female water polo players, we conclude that (a) anthropometric characteristics are different from those presented by other selections of a similar level that have been examined recently; (b) training throwing velocities are higher than those shown in other studies with a lower skill level sample; (c) in the zone close to the goal, precision and accuracy are more important than throwing velocity; and (d) throwing velocity is faster in competition than in training. For these reasons, knowledge of the characteristics of elite water polo players can be used by coaches in appropriate selection and preparation methods.

Acknowledgments

The authors want to thank the Spanish Royal Swimming Federation and the LEN for the facilities contributed for measuring in the 2008 Water Polo European Championships. This Research is supported by a grant by the Spanish Ministry of Science and Innovation (DEP2008-06114). The results from this study do not constitute endorsement of the products by the authors or by the National Strength and Conditioning Association.

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