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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

Influence of maturity status on morphology, grip and throwing speed in young elite water polo players

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ABSTRACT

BACKGROUND: Water polo is a team sport that requires not only high levels of power and strength but a robust morphology with big body dimensions for an optimal performance. The aim of this study was to analyze the relationship between anthropometric variables, maturity, grip strength and throwing speed in young water polo competitors.

METHODS: Body composition, biological age, grip strength and throwing speed were evaluated in 28 elite water polo players (15.74±0.83 years old) with competition experience (7.35±1.68 years). The participants were divided into two maturity groups based on the percentage of adult height attained at the moment of assessment (<98% and >98%).

RESULTS: Significant differences and moderate effect sizes were observed across sitting height and upper body lengths and breadths in the more mature players of the >98% group compared with those observed in the <98% group (d>0.42; P<0.05). A large effect size in maturity status and percentage of adult height (d>0.82) was also identified in the >98% players. In addition, significant correlations (P<0.05) were determined between upper and lower body girths and not opposition throwing speed (NOT). Similarly, a linear regression analysis revealed that biacromial breadth, arm girth and medial calf skinfold significantly contributed in predicting NOT speed (r^2=0.82; P<0.01).

CONCLUSIONS: These findings suggest that body structure is positively related to throwing speed in young water polo players. Furthermore, the results of the present investigation might be useful for talent identification purposes.

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In the analysis of water polo performance, only a few determinants have been thoroughly studied, neglecting others with great importance such as anthropometric variables.[1-3] The research available on body composition in young players is scarce and does not take into account other factors such as biological maturity or training experience.[3, 4] The typical elite water polo player morphotype has been determined in senior categories.[5] In addition, Lovozina *et al.*[6] identified the anthropometric determinants of the most successful elite players, observing greater height, longer limbs, and biacromial breadths but lower waist girth than less successful players. Specifically, Borges *et al.*[3] found a relationship between hand grip strength and throwing speed (P=0.83; P<0.01), biacromial diameter and hand grip strength (P=0.53; P<0.01), and between biacromial diameter and throwing speed (P=0.67; P<0.01). Nevertheless, the relationship between physical fitness parameters, performance of technical-tactical actions and anthropometric parameters remains unknown.

Traditionally, the analysis of throwing speed and type has been performed under real conditions during competition[7] and in specific tests.[8] Previous studies have compared throwing speed and hand grip strength in senior players, reporting a strong relationship between maximum grip strength and throwing speed values, and between biacromial diameter and maximum grip strength.[9] In senior competitors, the presence of an opponent during a throw has been identified as a determinant not only for throwing speed but also for hand grip strength, especially in real situations.[10]

Age-group categories in water polo comprise two calendar years and are based on players' birth date. During adolescence, major physical and morphological changes are influenced by biological maturity and occur in short periods of time. Thus, huge differences in those attributes can be commonly observed in players competing at the same categories[11-13] Although important improvements can be identified in those parameters around the age at peak height velocity (APHV), each individual experiences a different tempo and timing of maturity even at the same chronological age.[14, 15] As a result of performance being partially determined by more robust morphotypes and better physical fitness levels at these stages, some young athletes can be underestimated or overestimated in their capacities when their biological maturity is not taken into consideration.[16]

Tsekouras *et al.*[17] stated that if a battery of psychological, anthropometric and physiological tests was performed, the determination of a comprehensive profile of the typical elite water polo player would be useful in daily practice for coaches and sports managers. Unfortunately, little scientific research has focused on the relationship of these parameters with biological maturity and throwing speed of elite players belonging to specific age groups. Therefore, the objective of this study was to analyze the maturity-related differences in the anthropometric characteristics, grip strength and throwing speed of high-level young water polo players.

Materials and methods

Design overview

A cross-sectional design (comparative description) was selected to investigate the differences in morphology, hand grip strength and throwing speed in young water polo players. Based on their maturity status (independent variables), the participants were allocated into two groups. A battery of anthropometric and strength test was used as dependent variables in order to provide a detailed profile of the players and the influence of their biological age on the most representative parameters. Moreover, all throwing speed tests were performed indoor to avoid wind influence on the results. To ensure an optimal fitness level by the players at the moment of the assessment, the study was conducted during the competition phase of the regular season. Training volume was not collected as a variable since all participants were considered elite players training on regular basis.

Participants

Twenty-eight young male water polo players with a mean age of 15.74±0.83 years (mean±SD) and a training experience of 7.21±1.71 (mean±SD) volunteered for this study. The inclusion criteria were: 1) training on a regular basis (at least 90 minutes per day and 5 days per week); 2) competing at national level; and 3) belonging to the same age group category (junior). The Institutional Ethical Committee approved the experimental procedures and all participants, and their parents/guardians were informed about the study procedures. Their consent forms were obtained before the beginning of testing. Any participant presenting disease or under pharmacological treatment during the measurement period was excluded from assessment.

Procedures

All participants completed a battery of anthropometric assessments during the mornings of two consecutive days. Throwing and strength tests were also performed on a separate day. Before the beginning of the warm-up, a clear explanation of the test procedures and a familiarization with the materials were provided. All participants completed a general warm-up consisting of 6-8 minutes of upper and lower limb dynamic stretching, followed by a 10-minute specific warm-up in the water supervised by a coach. To prevent any measurements negatively impacted by fatigue, all tests were conducted in the morning before the scheduled training session

Anthropometry and maturity

All measurements were taken following the procedures described by the International Society for the Advancement of Kinanthropometry (ISAK) by a level 3 certified anthropometrist. A SECA 862 (Seca GmbH, Hamburg, Germany) was used to determine body mass (kg), while heights (cm) and lengths (cm) were measured by a GPM anthropometer (Siber-Hegner, Zurich, Switzerland). Girths (cm) were determined by a metallic non-extensible tape Lufkin W606PM (Lufkin, Missouri City, TX, USA) and skinfold thickness (mm) was measured at eight sites (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh and medial calf) with a Harpenden skinfold caliper (Baty International, Burgees Hill, UK). The equation body mass (kg)/stretch stature (m^2) was used for Body Mass Index (BMI) calculations. All instruments were calibrated prior to each testing session to prevent any measurement errors. The variables were taken twice or three times, if the difference between the first two measurements was greater than 5% for the skinfolds and 1% for the other dimensions. The mean values or median values, in the case of the three measurements, were then used for subsequent data analysis.

The procedures described by Mirwald *et al.*[12] were followed to determine the age at peak height velocity (APHV) as an indicator of biological maturity. Since APHV was considered a maturational benchmark (0 value), each measurement was described as years from/to the peak height velocity (PHV) assuming the difference in years as a value of maturity offset. Thus, positive values indicated the years ahead of APHV, while negative values indicated the years remaining until APHV. Additionally, the prediction of adult height was measured following the guidelines defined by Sherar *et al.*[18] in order to allocate the athletes into two groups according to the percentage of their current height with respect to their predicted adult height: <98% and >98%.

Hand grip strength

The grip strength was measured by a hand grip strength test using a dynamometer TKK 5105 (Takei Scientific Instruments Co., Ltd., Tokyo, Japan). Participants were required to squeeze the dynamometer at maximum strength with the elbow at 90° while sitting in a chair.[19] An instructor that simultaneously encouraged athletes to do their best and hold the position for 3 seconds supervised all attempts. The best of three attempts to the nearest kilogram was taken for each hand and used for subsequent analysis. A rest time of at least 3 minutes was provided between each attempt.

Performance test

All participants completed two throwing speed tests at 5 m from the goal line, one with no opposition in front (NOT) and the other with the opposition (OT) of another athlete at a 1 m distance. A speed radar (StalkerPro Inc., Plano, TX, USA) allocated on the side of the pool and parallel to the action was used to determine the velocity of each throw (m/s). To prevent any measurement error, the throwing point and the goal were situated 3 m from the side of the pool. Participants performed three attempts of each type of throw with at least 5-minute rest in between but only the best was considered for subsequent analysis.

Statistical analysis

All statistical analyses were conducted using the software SPSS v. 24.0 (SPSS Inc., Chicago, IL, USA). Measures of homogeneity and spread were reported as mean±SD. The hypotheses of normality of the distribution and homogeneity of variance were investigated using the Kolmogorov-Smirnov Test and Levene's Test, respectively. The difference between the mean values of different groups was analysed using *t*-test for independent samples, or the Mann-Whitney Nonparametric Test when the normality assumption of the data was rejected. The level of statistical significance was set up at $P<0.05$. To examine the effect size of the observed differences, Cohen's *d* was used.[20] The interrelationship between anthropometry, strength and performance was determined using Pearson's correlation coefficient (*r*). When the normality assumption was violated, Spearman's correlation coefficient was used. Using the significant variables from the linear correlation, a stepwise multiple linear regression analysis was conducted to determine which ones could predict throwing speed. In addition, collinearity was analysed using the Variance Inflation Factor (VIF), excluding predictor variables from the model when VIF values were greater than 10.

Results

The anthropometric characteristics for both groups, >98% and <98% of predicted adult height, are presented in Supplementary Digital Material 1: Supplementary Table I. Significant differences between group means ($P<0.05$) were identified in age and sitting height. Hand length and humerus and femur breadths were also significantly larger in the >98% group compared with the <98% group. Cohen's *d* analysis revealed small to large effect sizes with *d* values ranging from 0.42 to 0.82.

Table I summarizes the mean values of the biological maturity, strength and performance characteristics according to the two predicted-adult-height-based groups. Only maturity status and percentage of adult height revealed significant differences ($P>0.01$) and large effect sizes ($d>0.83$). Although no significant differences between groups were observed in hand grip and throwing speed, greater values were detected in the>98% water polo players for all variables.

The results of the interrelationships between speed

TABLE I.—*Mean values of the maturity, strength and performance characteristics for the two groups based on the current percentage of predicted adult height.*

Variables	>98% Adult height (N.=16)		<98% Adult height (N.=17)		P	Effect size (Cohen's *d*)
	Mean±SD	95% CI	Mean±SD	95% CI		
Maturity (years from/to APHV)	2.87±0.57	2.56-3.17	1.36±0.57	1.07-1.66	<0.01*	0.81
APHV (years)	13.46±0.65	13.11-13.8	13.56±0.55	13.27-13.84	0.64	0.08
Predicted adult height (cm)	179.72±7.15	175.9-183.53	179.24±8.28	174.99-183.5	0.86	0.03
% Of adult height (cm)	99.23±0.59	98.92-99.54	96.42±1.98	95.4-97.44	<0.01*	0.79
NOT (m/s)	16.75.3±1.52	15.87-17.63	16.49±1.45	15.66-17.27	0.64	0.09
OT (m/s)	16.09±2.47	14.66-17.52	15.29±2.12	14.16-16.43	0.35	0.18
Right hand grip strength (kg)	59.23±5.73	55.58-62.87	54.79±10.6	48.39-61.2	0.21	0.26
Left hand grip strength (kg)	58.23±8.83	53.13-63.32	56.46±8.04	52.18-60.75	0.57	0.11

*Statistically significant.
APHV: Age at peak height velocity; NOT: no opposition throw; OT: opposition throw.

TABLE II.—*Relationship between throwing speed and morphology, maturity and strength.*

Variables	NOT (m/s)	OT (m/s)
Age (years)	0.309	0.042
Body mass (kg)	0.536*	0.128
Height (cm)	0.672*	-0.252
Sitting height (cm)	-0.109	0.219
BMI (kg m^{-2})	0.139	0.338
Arm span (cm)	0.683*	-0.058
Triceps skinfold (mm)	-0.138	0.102
Subescapular skinfold (mm)	0.065	0.090
Biceps skinfold (mm)	-0.338	0.064
Iliac crest skinfold (mm)	-0.016	0.113
Supraespinale skinfold (mm)	-0.178	0.086
Abdominal skinfold (mm)	-0.031	0.109
Front thigh skinfold (mm)	-0.344	0.124
Medium calf skinfold (mm)	-0.463*	0.141
Sum of 8 skinfolds (mm)	-0.191	0.124
Sum of 6 skinfold (mm)	-0.213	0.127
Arm girth relaxed (cm)	0.456*	0.138
Arm girth flexed and tensed (cm)	0.602*	0.154
Corrected arm girth (cm)	0.436*	0.022
Chest girth (cm)	0.291	-0.055
Waist girth (cm)	0.409*	0.170
Gluteal girth (cm)	0.452*	0.107
Hand length (cm)	0.463*	0.076
Foot length (cm)	0.224	-0.018
Biacromial breadth (cm)	0.819*	-0.018
Biiliocristal breadth (cm)	0.245	0.019
Transverse chest breadth (cm)	0.358	0.310
A-P Chest depth (cm)	0.155	0.174
Humerus breadth (cm)	-0.019	-0.145
Femur breadth (cm)	0.119	0.082
Wrist breadth (cm)	0.081	0.058
Maturity (years from/to APHV)	0.138	0.198
APHV (years)	0.272	-0.275
Predicted adult height (cm)	0.639*	-0.306
% of adult height (cm)	0.148	0.154
Right Grip Strength (kg)	0.178	0.936*
Left Grip Strength (kg)	0.074	0.975*

*Statistically significant.
BMI: Body Mass Index; A-P: anterio-posterior; APHV: age at peak height velocity; NOT: no opposition throw; OT: opposition throw.

and maturity, strength and morphological parameters are shown in Table II. NOT was positively associated with the basic anthropometric characteristics (r>0.54; P<0.05), whereas negative correlations were identified between medial calf skinfold and NOT speed (r=-0.46; P<0.05). Arm and lower body girths, hand length and biacromial breadths presented significant and positive correlations with NOT, observing r values from 0.41 to 0.82. In addition, the analysis of biological maturity revealed a significant relationship between predicted adult height and NOT (r=0.64; P<0.05). However, the only observed correlation concerning OT speed was determined with both right- and left-hand grip strength (r>0.94).

The determining factors that predict NOT speed were analysed by a stepwise linear regression equation and presented in Table III. Biacromial breadth, arm girth flexed and tensed, and medial calf skinfold significantly contributed to predict NOT speed (r^2=0.82; P<0.01).

Discussion

The aim of this study was to analyze the relationship between anthropometric variables, maturity status, hand grip strength and throwing speed in young elite water polo players. The main findings of this research were the superior body dimensions, especially in the breadths of the upper and lower limbs of the more mature players. Conversely, no statistical significance was determined in the comparison of hand grip strength and throwing speed between maturity groups. In the analysis of the determining factors that predict throwing speed, arm girth and biacromial breadth significantly contributed to predict NOT speed. Since the current study is the first in analyzing the relative importance of biological age on water polo determinants and the predictors of throwing speed at early ages, the results provided here might contribute to the identifi-

TABLE III.—*Regression equation to predict NOT speed.*

Throw	Equation	r^2	SEE
NOT (m/s)	-14.61+1.56×(biacromial breadth)-0.37×(medial calf skinfold)+0.55×(arm girth flexed and tensed)	0.82	2.47

NOT: No opposition throw.

cation of the necessary parameters for more appropriate and coherent training programmes according to game requests.[21]

In the present study, it is noteworthy that the basic anthropometric variables such as body mass, height and arm span, showed higher values than those reported by Enseñat *et al.*[22] in young Spanish water polo players. When the results obtained here by the more mature group were compared with most recent findings by Gullikson *et al.*[23] in older American university water polo players, slightly lower values were observed in body mass (64.84 *vs*. 71.3 kg, respectively), height (177.6 *vs*. 182.2 cm, respectively) and arm span (182.39 *vs.* 186.6 cm, respectively). According to Gómez-García *et al.*[24] these factors are considered a competitive advantage in game situations such as gaining possession, jumping over water for blocking, throwing and opposing.[25] Thus, they are identified as the main morphological variables to be taken into account to generate a greater sport performance.

Prior research on biological maturity has revealed the great influence of this parameter not only on physical capacities but also on body composition.[15, 16, 26] In agreement with these findings, the results observed here revealed greater basic anthropometric values and significantly longer hand dimensions in the more mature group (>98%). Since a more robust and compact morphotype benefits performance in these types of physical sports,[27] maturity status seems a major determinant for success at early ages. In fact, previous studies in individual sports have reported that biological maturity was a more important factor in performance than chronological age.[28] Therefore, observing the changes in body composition alongside maturity levels is recommended during childhood and adolescence in order to identify potentially successful players who may be overlooked if only their anthropometric and psychical characteristics were to be considered.

As for the throwing speed analysis, contradictory results were found in the literature. Lower values were observed in the present study in comparison with the findings from Gullikson *et al.*[23] in young but relatively older players. They reported throwing speeds ranging between 13.7 and 18.9 $m.s^{-1}$. Bloomfield *et al.*[29] reported slightly greater speed throws in Australian athletes (16.5-16.87 $m.s^{-1}$). However, these data must be treated and compares with caution due to the huge differences in the level of water polo players and throwing conditions amongst the participants of these investigations. Accordingly, Ferragut *et al.*[10] have reported evidence of significantly higher throwing speeds during competition than in individual assessments during training. In addition, significant differences have been reported when throwing with or without an opponent present.[9] Grip strength appears to be more important in throws where opposition or a goalkeeper is present, since throwing speed and hand grip strength were only associated in those situations.[9] Although these findings were observed in senior players, similar relationships were found in the present study. Hence, in the investigation of throwing speed, different types of throws, including defensive strategy variations and previous movement patterns should be taken into consideration to better simulate and reproduce the real conditions of the game.

According to the model described by Argudo *et al.*[30] throwing speed predicted 65% of the goals and 62% of the failures in situations of inequality or counterattack. It seems relevant to investigate whether there are trainable morphological variables which allow for greater throwing performance in water polo. In this sense, throwing speed is considered one of the main factors associated with water polo success, as faster throws reduce the time available for defenders and goalkeepers to block or stop the throws.[31] According to the results of the present investigation, NOT was positively associated with the basic anthropometric characteristics and upper body girths and breaths. Similarly, the analysis of the variables predicting NOT speed, indicated a remarkable contribution of bigger and wider upper body structures. Therefore, these results might suggest that body composition and throwing speed are indeed associated since bigger and stronger players also attained greater NOT velocities. Nevertheless, when observing OT speed, significant high correlations were only determined with right- and left-hand grip. This might demonstrate the great importance of arm dimensions and hand strength to achieve high speed throws and thus better performances in water polo. These findings might be explained by the higher levels of motivation in OT to beat an opponent with respect to the NOT findings that have been previously reported by van der Vende.[8]

Another factor influencing throwing speed that should not be underestimated is throwing force.[16] Previous studies by Alcaraz *et al.*[32, 33] have revealed significant correlations between hand grip strength and upper and lower limbs morphology, such as biacromial and femur breadths. Similarly, Borges *et al.*[3] reported that throwing speed requires considerable muscle strength, observing also significant correlations between arm length and throwing speed. In addition, Borges *et al.*[3] revealed correlations between femur diameter and throwing speed in situations with goalkeepers, similar to those reported by Vila *et al.*[2] However, contradictory results were found by Ferragut *et al.*[10] about relative contributions of these parameters to throwing speed, all in agreement with the findings of the current study.

Limitations of the study

Although superior body dimensions in upper and lower limbs have been related to higher force application in the throws, prior research has suggested that the differences in performance levels relayed more on technical-tactical skills rather than in morphological differences.[34] However, this has been one of the limitations of this study, which did not consider analyzing the athlete's technical execution or previous swimming speed; it was considered that, due to their high performance level, all players would exhibit an adequate throwing execution. Traditionally, these factors and other secondary abilities such as speed of travel and swimming efficiency have been identified as contributing factors to water polo performance.[35] Unfortunately, more research is needed to confirm this hypothesis.

Based on these findings, biological maturity and morphological development patterns might positively contribute, not only to a more effective talent identification protocol for players, but also to more adequate training programs according to the characteristics of the athletes and the demands of the competition.[24] The utility of longitudinal and morphological studies demonstrating the maturational characteristics of the athletes must be taken into consideration to manage the progression and biological growth of the young players and also for comparative purposes with other national and international competitors. Furthermore, they would allow for accurate monitoring of training stages to better understand how the sport evolves over time, both due to regulatory modifications and due to technical advancements in the training methods. Therefore, the determination of morphological and physical fitness profiles at young ages seems paramount for talent identification programs in water polo.[34]

Conclusions

According to the findings of this research, water polo players with higher maturity status demonstrated greater body dimensions but not significantly greater throwing speeds. In addition, throwing speed with opposition (OT) and without opposition (NOT) was influenced by different factors. Apparently, a bigger and more compact morphotype would be related to NOT, while OT speed would be more associated with hand grip strength. These findings are in agreement with previous studies on water polo performance, confirming the importance of anthropometry and hand grip strength. Since biological maturity is highly related to the evolution of physical structure and body composition, special attention must be given to talent identification programs and training plans. Similarly, the results of the present investigation might be helpful for coaches to design training programs specifically aimed at each athlete, taking into account their individual characteristics and to better select and prepare future elite players for particular playing positions.[36]

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