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Position Specific Morphological Characteristics of Elite Water Polo Players

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A B S T R A C T

The aim of the study was to determine morphological characteristics of elite water polo players. In a sample of 121 water polo players, the structure of a set of 23 morphological space variables was determined by use of factor analysis, followed by determination of differences between all pairs of playing positions in the manifest morphological space by use of Post Hoc analysis. Factor structure indicated the presence of four basic superior latent dimensions responsible for directly measurable manifestations of morphological parameters: first component acting as a general mechanism of growth and development; second component being bipolar, at one pole almost exclusively determined by adipose tissue, and on the other pole by longitudinal skeletal growth; third component differentiating longitudinal skeletal growth accompanied by subcutaneous adipose tissue from muscle mass development and transverse skeletal growth; and fourth component mostly differentiating transverse skeletal development relative to longitudinal skeletal development. Oblimin transformation of the main components was employed to define the factor of circular dimensionality, factor of subcutaneous adipose tissue, factor of longitudinal skeleton dimensionality, and factor of transverse skeleton dimensionality. Results of obtained by the analysis of variance (ANOVA) and homogenization of playing positions in water polo for each individual variable upon Post Hoc analysis yielded significant differences both within and between groups in all anthropometric variables except for the variable of triceps skinfold. Statistically significant differences were recorded between two groups of playing positions, i.e. centers and backs versus goalkeepers, wingers and outside forwards. Significant differences were found between water polo players playing at center and back positions, characterized by higher values of all measures of longitudinal and transverse skeleton dimensionality in comparison with water polo players playing at other positions (goalkeepers, wingers and outside forwards). Significant differences were observed according to body mass and volume between water polo players playing at center position, characterized by considerably higher values of all measures in comparison with water polo players at other positions, and between centers and backs versus other positions according to body weight, chest circumference and forearm circumference. Considering subcutaneous adipose tissue, skinfold variable was significantly more pronounced in water polo players playing at center position than in those playing at other positions.

Key words: *morphological characteristics, elite water polo players, factor analysis*

Introduction

Water polo is a team game with ball in water, predominated by complex movements. Modern water polo is characterized by fast and rapid actions with pronounced counter-attacks, strong and precise shoots at the goal, and firm contact play, requiring high-level psychomotor abilities of the players. In terms of energy it is classified in the category of mixed anaerobic-aerobic sports (50%–50%). The game is played by six players and a goalkeeper on either side. During the game, six players perform various tasks of both attack and defense type. Concerning the structure of water polo player's motion during the game, 35% of overall time the player is in the quasi-horizontal phase (all swimming at all levels of intensity during the game), whereas the remaining 65% of the time he is in the quasi-vertical phase (vertical positions achieved by leg work known as water polo cycling). Each players predominantly takes the role primarily intended for him, however, during the game he may find himself at positions that make him also take other roles. Five playing roles in water polo are defined as center, winger (left and right), back, outside forward (left and right), and goalkeeper. Considering movements and efficient technique

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performance, each of these roles requires different and specific morphological and motor characteristics. Therefore, the players able to perform best particular roles because of such a structure are allocated dominant roles by their coaches[1–10], i.e. players are allocated to particular playing positions according to their physical structure.

In any sports discipline, success is determined by an array of various inter-related anthropologic status dimensions, i.e. motor, functional, morphological, cognitive, conative and others. A number of these factors are being intertwined into a single structure that is responsible for task performance in water polo[11–15], and/or formation of an anthropologic structure appropriate for water polo players. Thus, water polo training also leads to adjustment of the morphological subsegment of the anthropologic structure, optimizing the morphological structure according to this particular sports discipline requirements.

The aim of the present study was to identify factor structure of anthropometric dimensions in water polo players, and then to determine morphological characteristics of elite water polo players in the manifest space of anthropometric variables according to playing positions, i.e. to identify the variables that predominantly differentiate morphological characteristics specific for particular playing position.

Factor analysis of the morphological space in the sample of water polo players is expected to isolate four dimensions (longitudinal skeleton dimensionality, transverse skeleton dimensionality, circular dimensionality, and subcutaneous adipose tissue factor), however, with a specific structure relative to previous studies in different subject samples[16–21]. In addition, relative to other playing positions, the Center (C) and Back (B) positions are expected to possess anthropometric measures for detection of longitudinal skeleton dimensionality (L), transverse skeleton dimensionality (T), circular dimensionality (CD), and subcutaneous adipose tissue (M) in the higher range of results[1–9].

Materials and Methods

Study design

Prior to measurements, four measurers underwent training and harmonization of measurements by assessing ten junior water polo players using all anthropometric measures. When a high level of agreement was achieved in measuring all variables, three measurers measured six variables each, and one measurer measured five variables. Measurements were taken in water polo players from one club per day, at swimming pools in Split, Šibenik, Dubrovnik and Sinj, always at the same time, from 6.00 p.m. to 9.00 p.m. On measurements, the subjects were wearing swimming trunks and barefoot. Anthropometric measures were taken by the method recommended by the International Biological Program (IBP)[22,23].

Subject sample

Study group included 121 water polo players from eight clubs of the First Water Polo Division, aged 17–27 and with continuous water polo training for 5–12 years. Active play in at least one Division game in the year of measurement was set as inclusion criterion. Because of this inclusion criterion, not all players (14 players under age 18) could be excluded where the growth and development may have not yet been fully completed because of their young age. This fact may have influenced the results obtained since morphological characteristics are not independent of age.

Variable sample

A set of 23 variables were used on morphological dimension assessment:

- longitudinal skeleton dimensionality: body height (mm), arm length (mm), leg length (mm), foot length (mm), hand length (mm);
- transverse skeleton dimensionality: shoulder width (mm), pelvis width (mm), wrist diameter (mm), elbow diameter (mm), knee diameter (mm), hand width (mm), foot width (mm);
- body mass and volume: body mass (dkg), upper arm circumference (mm), forearm circumference (mm), upper leg circumference (mm), lower leg circumference (mm), mean chest circumference (mm); and
- subcutaneous adipose tissue: axilla skinfold (1/10 mm), subscapular skinfold (1/10 mm), abdomen skinfold (1/10 mm), triceps skinfold (1/10 mm), lower leg skinfold (1/10 mm).

Data processing

Data obtained were processed by standard descriptive procedures to determine the functions of their distribution and the basic statistical parameters of these functions. Calculations included arithmetic mean (X), standard deviation (SD), minimal result (Min), maximal result (Max), asymmetry coefficient (Skew) and kurtosis coefficient (Kurt). The hypothesis of distribution normality was tested by Kolmogorov-Smirnov procedure according to which the hypothesis can be rejected with an error of 0.01.

Hotelling method of main components was employed to determine latent structure of the morphological space. In the present study, Guttman-Kaiser criterion was used, according to which the components with characteristic roots greater or equal to 1.00 are considered significant. The characteristic roots of the inter-correlation matrix were marked with λ. In addition to the size of characteristic roots, the relative cumulative contribution of each root to the explanation of the overall variable variance was also calculated. Then, oblimin rotation was performed and factor structure in oblimin solution calculated, followed by calculation of correlations among these factors[17–21].

Considering the objective of the study to identify substantial parameters in the manifest space that differentiate morphological characteristics specific for a particular role, analysis of variance (ANOVA) and Post Hoc analysis according to Scheffe were performed to determine the level of statistical significance between all pairs of playing positions.

Results

Table 1 shows statistical data on all anthropometric variables (minimal and maximal results, arithmetic mean and standard deviation, and third and fourth moment around arithmetic mean). Analysis of the results obtained revealed all anthropometric variables to follow normal or approximately normal distribution. The variable of axilla skinfold showed a low level of asymmetric distribution, while the variables of foot length and subscapular skinfold showed leptokurtic distribution. The system of anthropometric variables thus chosen is expected to prove functional in additional analyses.

Factor analysis using component model is illustrated in Table 2. The number of the main axes retained was determined by use of GK criterion ($\lambda>1$), according to which the component with the characteristic value (λ) exceeding 1 is considered significant. The four main components explained 70.85% of total variance.

The communalities of anthropometric variables used in the study were fairly high, ranging from 0.932 to 0.537, with the only exception of the anthropometric variable of shoulder width with a very low communality (0.415).

The first main component was found to be responsible for 38.36% of variance from overall co-variability. It was defined by high projections of almost all anthropometric variables, showed a pattern of the general factor of growth and development, and represented the main subject of measurement of all elements of the morphological system of variables.

The second main component was responsible for 17.92% of variance from overall co-variability. It was defined by high positive projections of the measures of subcutaneous adipose tissue (subscapular skinfold, axilla skinfold, abdominal skinfold and lower leg skinfold) and associated measures with negative projections, used for detection of longitudinal skeleton dimensionality (hand length, arm length, leg length, foot length and body height). This component dominantly differentiates the amount of adipose tissue from skeletal length.

The third main component, found to be responsible for 7.69% of variance from overall co-variability, was de-

TABLE 1
DESCRIPTIVE STATISTICS OF ANTHROPOMETRIC VARIABLES (N=121)

Variable	X	SD	Min	Max	Skew	Kurt
Body height	192.26	6.41	177.80	205.60	0.102	–0.608
Leg length	108.31	5.04	87.90	119.10	–0.412	1.315
Arm length	85.58	3.56	76.80	94.30	0.140	–0.388
Hand length	19.24	0.80	16.80	21.40	–0.233	0.279
Foot length	27.56	1.57	20.10	31.00	–0.484	3.560
Shoulder width	43.90	1.96	39.00	48.00	–0.206	–0.396
Pelvis width	29.45	1.88	25.00	34.00	–0.019	–0.437
Hand width	89.30	3.82	80.00	103.00	0.369	1.410
Foot width	103.50	5.32	93.00	119.00	0.289	–0.052
Wrist diameter	61.50	2.98	55.00	69.00	–0.069	–0.309
Elbow diameter	74.11	3.95	62.00	88.00	0.324	1.228
Knee diameter	100.68	5.00	90.00	112.00	–0.270	–0.525
Body mass	93.62	10.80	76.00	120.00	0.742	0.067
Upper arm circumference	34.44	2.29	29.00	39.00	0.043	–0.495
Forearm circumference	29.33	1.34	26.20	32.50	0.105	–0.534
Upper leg circumference	61.70	4.27	53.40	76.00	0.424	0.260
Lower leg circumference	39.29	2.29	31.10	47.20	0.096	1.505
Mean chest circumference	108.18	6.39	95.10	128.20	0.487	–0.051
Triceps skinfold	8.51	2.78	4.00	18.40	0.892	1.326
Subscapular skinfold	10.66	3.28	5.60	24.40	1.622	3.365
Axilla skinfold	9.05	4.18	4.10	32.20	2.066	7.213
Abdomen skinfold	13.92	6.38	5.00	33.00	1.072	0.665
Lower leg skinfold	9.13	3.99	3.60	28.20	1.424	3.710

X – arithmetic mean, SD – standard deviation, Min – minimal result, Max – maximal result, Skew – coefficient of asymmetry, Kurt – coefficient of kurtosis

TABLE 2
MAIN COMPONENTS OF ANTHROPOMETRIC VARIABLES IN WATER POLO PLAYERS (N=121)

Variable	H1	H2	H3	H4	h^2
Body height	0.688	–0.510	0.326	–0.162	0.866
Leg length	0.579	–0.559	0.398	–0.115	0.819
Arm length	0.564	–0.540	0.468	–0.178	0.860
Hand length	0.466	–0.547	0.238	0.078	0.578
Foot length	0.526	–0.536	0.237	0.120	0.634
Shoulder width	0.466	–0.082	0.024	–0.437	0.415
Pelvis width	0.787	0.053	0.039	–0.006	0.624
Hand width	0.535	–0.323	–0.348	0.220	0.559
Foot width	0.546	–0.473	–0.175	0.263	0.622
Wrist diameter	0.598	–0.202	–0.124	0.351	0.537
Elbow diameter	0.648	–0.304	–0.239	–0.010	0.570
Knee diameter	0.570	–0.114	–0.154	0.506	0.618
Body mass	0.945	0.075	–0.048	–0.177	0.932
Upper arm circumference	0.729	0.422	–0.343	–0.222	0.876
Forearm circumference	0.812	0.118	–0.399	–0.139	0.852
Upper leg circumference	0.778	0.375	–0.119	–0.063	0.764
Lower leg circumference	0.669	0.075	–0.316	0.216	0.600
Mean chest circumference	0.763	0.273	–0.158	–0.345	0.801
Triceps skinfold	0.275	0.438	0.424	0.506	0.704
Subscapular skinfold	0.510	0.656	0.280	–0.053	0.771
Axilla skinfold	0.471	0.667	0.352	–0.079	0.796
Abdomen skinfold	0.517	0.657	0.298	–0.043	0.790
Lower leg skinfold	0.371	0.521	0.182	0.515	0.708
λ	8.824	4.122	1.768	1.582	
Variance %	38.364	17.921	7.686	6.878	

H – main component of inter-correlation matrix, h^2 – communality of measuring instruments, λ – characteristic root (Lambda), Variance % – percentage of explained variance

fined by longitudinal measures (leg length, arm length and body height) of positive sign and associated skinfold measures (triceps skinfold and axilla skinfold) of the same sign, and by volume variables (upper arm circumference, forearm circumference and lower leg circumference) and to a minor extent by the variables of transverse skeleton dimensionality of inverse, i.e. negative sign. However, this component in fact differentiated longitudinal skeleton development accompanied by subcutaneous adipose tissue from muscle mass development and transverse skeleton development.

The fourth main component was responsible for 6.88% of variance from overall co-variability. It was defined by the variables of knee diameter and wrist diameter, triceps skinfold and lower leg skinfold of positive sign, along with the associated variables of shoulder width and chest span and circumference of negative sign. This component mostly differentiated transverse skeleton development from longitudinal skeleton development.

Oblimin transformation of latent dimensions obtained by orthoblique transformation of characteristic vectors of the matrix of variable inter-correlations was performed to obtain a simpler structure (Table 3).

The structure of the first factor was predominantly defined by the variables of chest circumference, upper arm circumference, forearm circumference and upper leg circumference, along with the associated variable of body weight. This factor could be termed factor of body mass and volume.

The second factor structure was very neatly defined by skinfold measures (subscapular skinfold, triceps skinfold, axilla skinfold, abdominal skinfold and lower leg skinfold) with high coefficients of influence. This factor could be defined and termed as a pure factor of subcutaneous adipose tissue (skinfolds).

The structure of the third factor was defined by the variables of hand length, arm length, leg length, foot length and body height, and by the associated variable of body weight, with high coefficients of influence. In addition, this factor was also defined by all measures used to detect transverse skeleton dimensionality, however, with

TABLE 3
OBLIMIN FACTORS (OBL) OF ANTHROPOMETRIC VARIABLES IN WATER POLO PLAYERS (N=121)

Variable	OBL1	OBL2	OBL3	OBL4
Body height	0.143	–0.002	0.876	0.011
Leg length	–0.008	0.013	0.913	–0.018
Arm length	–0.002	0.033	0.961	–0.119
Hand length	–0.118	–0.012	0.703	0.193
Foot length	–0.108	0.030	0.712	0.243
Shoulder width	0.523	–0.145	0.325	–0.194
Pelvis width	0.453	0.245	0.304	0.204
Hand width	0.211	–0.174	0.102	0.629
Foot width	0.042	–0.123	0.331	0.598
Wrist diameter	0.087	0.127	0.205	0.587
parElbow diameter	0.386	–0.183	0.258	0.413
Knee diameter	0.013	0.233	0.089	0.697
Body mass	0.714	0.151	0.312	0.165
Upper arm circumference	0.906	0.086	–0.217	0.159
Forearm circumference	0.810	–0.065	–0.050	0.358
Upper leg circumference	0.690	0.300	–0.018	0.174
Lower leg circumference	0.425	0.112	–0.072	0.553
Mean chest circumference	0.858	0.065	0.057	–0.004
Triceps skinfold	–0.247	0.864	0.079	0.121
Subscapular skinfold	0.431	0.666	0.012	–0.211
Axilla skinfold	0.393	0.697	0.050	–0.290
Abdomen skinfold	0.418	0.685	0.027	–0.212
Lower leg skinfold	–0.041	0.783	–0.129	0.285

lower yet significant coefficients of influence. This factor was termed longitudinal skeleton dimensionality (lengths).

The structure of the fourth factor was defined by the variables of hand width, wrist diameter, elbow diameter, knee diameter and foot width, and the associated variable of lower leg circumference, with high and significant impact coefficients. As this factor was in fact defined by all measures used to detect transverse skeleton dimensionality, it could be defined as a factor of transverse skeleton dimensionality (widths).

Factor correlations were low, suggesting them all to exist independently (Table 4). The third and fourth factors yielded a somewhat higher correlation (0.328), which could be logically explained considering that both belong to the same, skeletal system. Longitudinal and transverse bone growth probably share in part the origin of generation, while in part following distinct routes of formation.

TABLE 4
FACTOR INTER-CORRELATION

Factor	1	2	3	4
Body mass and volume	1.000	0.276	0.286	0.221
Adipose tissue	0.276	1.000	–0.034	0.073
Skeleton length	0.286	–0.034	1.000	0.328
Skeleton width	0.221	0.073	0.328	1.000

The level of between-group significance was calculated by the analysis of variance (ANOVA) and tested by F-test at the level of significance of $p<0.05$. The results obtained pointed to significant between-group differences in all anthropometric variables, with the exception of the variable of triceps skinfold (Table 5).

Pos Hoc analysis according to Scheffe was performed to determine statistically significant differences between all pairs of playing positions. Analytical results are reported for those morphological variables that are substantial for the assessment of hypothetical morphological factors and are superior in differentiating particular playing positions.

The five playing positions formed two subgroups according to the variable of body height. One subgroup included the winger, outer forward and goalkeeper, and the other included the goalkeeper, center and back. While the winger and outer forward positions do not require very high stature to perform their tasks during the game, it is required at center and back positions. Goalkeepers were present in both subsets; with the body height in-between the two subgroups, they obviously represented a specific structure where such a body height is optimal for specific task performance.

The five playing positions formed two subgroups according to the variable of arm length. One subgroup included the positions of outer forward, winger, goalkeeper and center, and the other included the goalkeeper, center and back. Goalkeepers and centers were present in both subgroups. Long arms (arm span) are need at both positions: to perform defense techniques at the position of goalkeeper and for game performance at two meters at the position of center. In the second subgroup, the goalkeepers and centers had shorter arms than backs, although there was no statistically significant within-group difference. Even longer arms are required at the back position on performing defense tasks against centers.

The five playing positions formed two subgroups according to the variable of shoulder width. One subgroup included the winger, goalkeeper, outer forward and back positions, and the other included the goalkeeper, outer forward, back and center positions. The winger was least likely to appear in the first subgroup, whereas Center was most likely to appear in the second subgroup. The winger is characterized by such a shoulder width due to his contact-free play, while his role is defined by attempting counterattacks, ball transmission in attacks and closing the opponent's counterattacks. The highest value of shoulder width in forwards in the second subgroup could be attributed by extraordinary dimensionality of the upper trunk (shoulder girdle), determined by the superior horizontal axis (shoulder width), indirectly suggesting great strength that is required from the center.

The five playing positions produced two subgroups according to the variable of wrist diameter. One subgroup

TABLE 5
ANALYSIS OF VARIANCE (ANOVA) RESULTS AND HOMOGENIZATION OF PLAYING POSITIONS FOR PARTICULAR VARIABLES AFTER POST HOC ANALYSIS (PostHoc Tests)

Variable	Goalkeeper	Back	Winger	Outer forward	Center	F	p<
	(n=18)	(n=23)	(n=30)	(n=28)	(n=22)		
	X	X	X	X	X		
Body height	192.26[1,2]	196.80[2]	188.15[1]	189.91[1]	196.11[2]	12.21	0.001
Leg length	108.48[1,2,3]	111.82[3]	106.03[1]	106.25[1,2]	110.23[2,3]	7.73	0.001
Arm length	85.66[1,2]	87.94[2]	84.21[1]	84.05[1]	86.86[1,2]	6.72	0.001
Hand length	19.06[1]	19.57[1]	19.07[1]	19.09[1]	19.49[1]	2.54	0.044
Foot length	27.13[1]	28.43[2]	26.80[1]	27.12[1]	28.58[2]	8.41	0.001
Shoulder width	43.56[1,2]	44.52[1,2]	42.97[1]	43.64[1,2]	45.15[2]	5.48	0.001
Pelvis width	28.78[1,2]	30.00[2,3]	28.33[1]	29.46[1,2,3]	30.95[3]	9.17	0.001
Hand width	87.78[1]	91.09[1]	88.57[1]	88.50[1]	90.68[1]	3.55	0.010
Foot width	102.78[1,2]	105.83[2,3]	101.83[1,2]	100.89[1]	107.23[3]	7.70	0.001
Wrist diameter	60.78[1]	62.39[1,2]	61.23[1,2]	60.04[1]	63.41[2]	5.51	0.001
Elbow diameter	72.11[1]	75.39[1,2]	73.13[1]	73.36[1,2]	76.68[2]	5.52	0.001
Knee diameter	99.56[1,2]	102.57[2]	98.13[1]	100.29[1,2]	103.59[2]	5.66	0.001
Body mass	88.09[1]	99.03[2]	86.59[1]	90.64[1]	105.89[2]	23.51	0.001
Upper arm circumference	32.53[1]	34.83[2,3]	33.81[1,2]	34.32[1,2]	36.59[3]	11.89	0.001
Forearm circumference	28.32[1]	29.80[2,3]	28.79[1,2]	29.15[1,2]	30.61[3]	13.62	0.001
Upper leg circumference	60.40[1]	62.10[1]	59.57[1]	60.80[1]	66.42[2]	13.14	0.001
Lower leg circumference	38.33[1]	39.60[1,2]	38.46[1]	38.84[1]	41.44[2]	8.85	0.001
Mean chest circumference	104.06[1]	110.74[2,3]	105.26[1]	107.94[1,2]	113.16[3]	10.05	0.001
Triceps skinfold	8.54[1]	7.86[1]	7.84[1]	8.75[1]	9.78[1]	2.01	0.100
Subscapular skinfold	9.71[1]	11.15[1,2]	9.24[1]	10.28[1]	13.36[2]	6.85	0.001
Axilla skinfold	8.17[1]	9.16[1,2]	8.13[1]	8.26[1,2]	11.89[2]	3.66	0.010
Abdomen skinfold	12.41[1]	13.62[1]	11.96[1]	13.15[1]	19.12[1]	5.43	0.001
Lower leg skinfold	7.89[1]	8.71[1]	8.12[1]	8.95[1,2]	12.21[2]	4.80	0.001

[1,2,3] – allocation of playing positions to particular subgroups according to study variables

consisted of the outer forward, goalkeeper, winger and back, and other of the winger, back and center. Wrist diameter has a major role in contact play between the back and center (grasping the wrist and freeing from the grasp over the thumb), therefore a greater wrist diameter is a desirable feature.

The five playing positions produced two subgroups according to the variable of body weight, at the level of statistical significance of $p<0.05$. One subgroup included the positions of winger, goalkeeper and outer forward, and the other the positions of back and center. As the winger, goalkeeper and outer forward perform their tasks without playing contact, body mass is not substantial for their performance. Quite opposite is the situation at center and back positions exposed to contact play, where body mass is decisive for their performance.

The five playing positions yielded three subgroups according to the variables of upper arm circumference and of forearm circumference. The first group with the lowest values of upper arm circumference consisted of the goalkeeper, winger and outer forward positions characterized by contact-free play. The second group included the winger, outer forward and back positions, and the third group included back and center positions characterized by the greatest upper arm circumference and forearm circumference due to contact play that requires greater strength.

The five playing positions yielded two subgroups according to the variable of upper leg circumference. One subgroup included winger, goalkeeper, outer forward and back positions, whereas the other subgroup included center position. Upper leg circumference has a major role in water polo in both the horizontal and vertical phase of the game (all swimming and vertical positions are organized by water polo bicycling). As the upper leg circumference is a crucial strength indicator, it is quite conceivable for the center player to differ from other positions in this very variable because he requires more strength than any other position.

The five playing positions produced three subgroups according to the variable of chest circumference. The first subgroup with lowest values of chest circumference consisted of the goalkeeper, winger and outer forward positions characterized by contact-free play. The second subgroup included outer forward and back positions with somewhat higher values of chest circumference. In case of back position, it is easily explained by the tasks performed during the game, whereas outer forward probably joined this subgroup due to his play in defense taking the role of back. The third subgroup included back and center positions with highest values of chest circumference. It is logical because of the respective tasks during the game, especially when these players come in contact and collision.

The five playing positions yielded two subgroups according to the variable of subscapular skinfold. One subgroup included winger, goalkeeper, outer forward and back positions, and the other included back and center positions. Subcutaneous adipose tissue in the upper trunk region was obviously less pronounced in the players at winger, goalkeeper and outer forward positions, and considerably more pronounced in those playing at back and center positions. Such a distribution of subcutaneous adipose tissue in the upper trunk region influences the players' body mass as well as the organization of equilibrium positions.

The five playing positions produced two subgroups according to the variable of abdominal skinfold. One subgroup included winger, goalkeeper, outer forward and back positions, and the other included center position. Water polo players at winger, goalkeeper, outer forward and back positions had an appropriate amount of subcutaneous adipose tissue in the abdominal region, whereas the higher amount of subcutaneous adipose tissue in abdominal region recorded in the center served to form total body mass that is highly relevant at this position.

Discussion

Analysis of the main components of morphological variables provided solutions that could be reasonably interpreted in terms of taxonomy. The first main component acted as a general factor of growth and development, and it is responsible for the formation of specific and basic morphological structure in water polo players. The first main component of the morphological set of variables relative to 70.85% of total variance accounted for as much as 38.36% of variance among water polo players. Relative to the structure of the first main component, pronounced body mass and volume, along with pronounced skeletal development in terms of length and width are predominant morphological characteristics of elite water polo players; this is, to a lesser extent, accompanied by the projections of subcutaneous adipose tissue that is, among others, formed under the influence of body adaptation to water as a specific medium of water polo.

The second main component indicated the subcutaneous adipose tissue and longitudinal skeleton dimensionality to be inversely proportionate in water polo players; thus, this component predominantly differentiated development, i.e. adipose tissue formation, from longitudinal skeleton development.

The third main component differentiated longitudinal skeleton development accompanied by subcutaneous adipose tissue from muscle mass development and transverse skeleton development.

The fourth main component mostly differentiated transverse skeleton development from longitudinal skeleton development.

When the first main component determined general morphological structure found to be predominant in the majority of the study sample, the second, third and fourth main components as bipolar components differentiated morphological types of water polo players relative to differences in the development of morphological characteristics in a minor yet significant proportion of the study sample, as follows:

- second component differentiated water polo players with pronounced adipose tissue and below-average skeletal length from water polo players with below-average adipose tissue and above-average skeletal length;
- third component differentiated water polo players with above-average skeletal length and above-average adipose tissue, below-average muscle mass and below-average skeletal width from water polo players with below-average skeletal length and below-average adipose tissue, above-average muscle mass and above-average skeletal width; and
- fourth component differentiated water polo players with above-average skeletal width and below-average skeletal length from water polo players with below-average skeletal width and above-average skeletal length.

Oblimin transformation of the main components yielded a simple structure, i.e. the following morphological factors in water polo players: factor responsible for body mass and volume; factor responsible for the amount of adipose tissue; factor responsible for skeleton length; and factor responsible for skeleton width.

The results obtained by the analysis of variance (ANOVA) and homogenization of water polo playing positions for each individual variable following Post Hoc analysis revealed significant within-group and between-group differences in all anthropometric variables except for the variable of triceps skinfold.

Significant differences were recorded between the water polo players at center position, characterized by higher values of all measures, and those playing at other positions according to body mass and volume. Significant differences were also found in body weight, chest circumference and forearm circumference between the center and back players on the one hand and all other positions on the other hand.

Considering adipose tissue, skinfold variables were significantly more pronounced in water polo players at center position than in those playing at other positions.

According to skeleton length, significant differences were found between water polo players at back and forward positions, characterized by more pronounced measures of foot length, body height, arm length and leg length, and those playing at winger, outer forward and goalkeeper positions, the latter falling in-between the two groups according to these measures.

Skeleton width yielded significant differences between water polo players at the back and center positions, characterized by considerably more pronounced measures of foot width, elbow diameter and knee diameter, and those playing at the winger, outer forward and goalkeeper positions.

Statistically significant differences were recorded between two groups of playing positions, i.e. center and back positions on the one hand, and goalkeeper, winger and outer forward on the other hand. The center and back positions shared high results in all anthropometric measures used to detect longitudinal and transverse skeleton dimensionality. Also, center players showed very high results in all anthropometric variables used to detect body mass and volume, whereas back players had very high results in the variables of body weight, chest circumference and forearm circumference, and less so in the variables of upper arm circumference, upper leg circumference and lower leg circumference. Namely, for the center player to be efficient in attacking actions, he must be superior to the back as a defense player in (static, repetitive and explosive) strength factors of all body regions, both in controlling the opponent's load in contact play and on ball throw (in the order: leg strength, trunk strength, and arm strength)[2,5,6,8,11–15]. The more pronounced muscle mass in the center versus back placer contributes to this efficiency. Center player also had considerably higher values of the variables used to detect subcutaneous adipose tissue than other positions, whereas back position approached the structure of other playing positions in the variables of axilla skinfold, abdominal skinfold and lower leg skinfold. The goalkeeper, winger and outer forward positions showed quite uniform but lower values of all anthropometric status measures than back and center positions.

The present study provided comprehensive information on the morphological structures of elite water polo players and identified contribution of each individual morphological variable to differentiation of playing positions according to the factors identified.

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MORFOLOŠKE ZNAČAJKE VRHUNSKIH VATERPOLISTA U ODNOSU NA POZICIJU U IGRU

S A Ž E T A K

Istraživanje je imalo za cilj utvrditi morfološke značajke vrhunskih vaterpolista. U tu svrhu na uzorku od 121 vaterpolista primjenom faktorske analize utvrđena je struktura skupa od 23 varijable morfološkog prostora, a zatim su u manifesnom morfološkom prostoru primjenom Post Hoc analize utvrđene razlike između svih parova pozicija (uloga u igri). Faktorska struktura je pokazala kako su prisutne četiri osnovne nadređene latentne dimenzije odgovorne za izravno mjerljive manifestacije morfologijskih parametara. Prva komponenta se ponaša kao generalni mehanizam rasta i razvoja; druga je bipolarna, te je na jednom polu određena gotovo isključivo masnim tkivom, a na suprotnom rastom skeleta u dužinu; treća komponenta diferencira rast skeleta u dužinu, što prati potkožno masno tkivo, od razvoja mišićne mase i rasta skeleta u širinu, dok četvrta komponenta uglavnom diferencira rast skeleta u širinu u odnosu na rast skeleta u dužinu. Oblimin transformacijom glavnih komponenata definirani su: faktor cirkularne dimenzionalnosti, faktor potkožnog masnog tkiva, faktor longitudinalne dimenzionalnosti skeleta i faktor transverzalne dimenzionalnosti skeleta. Rezultati analize varijance (ANOVA) i homogenizacija pozicija u igri vaterpola za svaku pojedinu varijablu nakon Post Hoc analize su pokazali kako postoje značajne razlike unutar skupina, kao i između skupina u svim antropometrijskim varijablama osim u varijabli kožni nabor nadlaktice. Statistički značajno se razlikuju dvije grupacije uloga u igri: centri i bekovi na jednoj strani, te golmani, krila i vanjski igrači na drugoj strani. Utvrđene su značajne razlike između vaterpolista koji igraju na poziciji centra i beka sa znatno više izraženim svim mjerama longitudinalne i transverzalne dimenzionalnosti skeleta od vaterpolista koji igraju na ostalim pozicijama (golmani, krila i vanjski). U odnosu na volumen i masu tijela utvrđene su značajne razlike između vaterpolista koji igraju na poziciji centra sa znatno više izraženim svim mjerama od vaterpolista koji igraju na ostalim pozicijama, kao i značajne razlike između centra i beka i ostalih pozicija u težini tijela, opsegu prsnog koša i opsegu podlaktice. U odnosu na potkožno masno tkivo utvrđeno je da su kožni nabori značajno više izraženi kod vaterpolista koji igraju na poziciji centra od vaterpolista koji igraju na ostalim pozicijama.