MORPHOLOGICAL CHANGES IN ELITE MALE WATER POLO PLAYERS: SURVEY IN 1980 AND 2008

Mislav Lozovina[1], Vinko Lozovina[1] and Leo Pavičić[2]

[1] *Faculty of Maritime Studies, University of Split, Croatia*
[2] *Faculty of Kinesiology, University of Zagreb, Croatia*

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Abstract
Comparison between anthropometric measures of the two generations of water polo players revealed a positive trend in body skeletal measures (total arm length, hand breadth, height, biacromial breadth and negative trend in hand length). A positive trend is noted in circular dimensionality measures (chest girth, arm girth and forearm girth) and weight. Most noteworthy differences were an increase in total arm length, height and hand breadth and decrease in hand length. Cite variables statistical significantly discriminate generation "08" from "80" in manifest anthropometrical space. In latent space tree of five factors discriminate two generation. From discriminative factor structure is evident that factor of longitudinal dimensionality of skeleton has the biggest discriminative power. Weaker, but significant, groups discriminate third factor defined by hand length and foot length with added biiliocristal breadth of negative omen. Smaller but significant discriminative power of negative omen has the factor defined by measures of circular dimensionality with added weight and body mass index. Anthropometric characteristics of elite water polo players have changed over the analyzed 28 years. Body shape changed in terms of greater height and more elongated limbs, with thinner waist and broader shoulders. Body mass increased. Muscle-to-fat mass ratio increased. The observed changes are consequence of population secular trend and sport morphological adaptation (optimization).

Key words: *anthropometry; morphology; exercise; water polo; sports medicine*

Introduction

Variations in body size due to environmental influences are much larger than those resulting from genetic differences: Johnston FE. (1995). A trend of increasing body size and faster growth rate has been noted in industrialized countries since the middle of the 19th century, especially in the first half of 20th century: Tanner JM (1966), Ljung BO, Bergsten-Brucefors A, Lindgren G. (1974). This positive secular trend has largely been attributed to improving living conditions, nutrition, and control of infections: Van Wieringen JC. (1978), Tanner JM. (1986), Hauspie RC, Vercauteren M, Susanne C. (1997). The secular trend of increased stature observed during the last century amounted to 1.3 cm per decade by the end of childhood, 1.9 cm in mid-adolescence, and 0.6 cm at young adult age: Meredith HV. (1976). Different effects of sport activities (sport training) on growth and development have been summarized different publications and textbooks: Malina RM (1991), Malina at all (1991), Borms J, Hebbelinck M. (1984). The athlete's anthropometric dimensions, reflecting body shape, proportionality, and composition: Carter JE. (1970, 1984), play a significant role in determining the potential for success in sport: Battinelli T. (1990). Distinctive anthropometric characteristics come about by natural selection of successful athletes over successive generations and/or by an adaptation to the training demands within the present generation. The "final" body shape and composition in a given sport results from a phenomenon called "sport morphological optimization": Norton K, Olds T. (2001), Lozovina, V., Lozovina, M.(2008).

A number of differences in players' body morphology and composition: Lozovina V. (1986), Vujović D, Lozovina V, Pavičić L. (1986) due the environmental changes in general, and changes within the game of water polo itself: Pavičić L. (1991), Lozovina at all (2003) could be expected. The aim of this study was to determine the size and direction of changes in anthropometric characteristics of elite water polo players over 28-year time span.

Methods

Subjects
The sample consisted of 182 elite male water polo players from the top Croatian clubs. Anthropometric measures of 95 players (71.9% of the target population) were taken in 1980 (generation of 1980), and of 87 players in 2008 (generation of 2008). The age range of the generation of 1980 at the time of measurement was 18-32 years (mean ± standard deviation, SD, 21.2±4.0 years), and the age range of the generation of 2008 (72% of the target population) was 19-34 years (mean ± SD, 23.8 ± 3.8 years).

All participants were clinically healthy without morphological aberrations. The only inclusion criterion was participation in at least one official game as a member of the top national division in the year of measurement. There was no overlap between the two groups, i.e., none of the players was measured in both years.

Outcome Measures

Trained and qualified investigators performed all the measurements, using standardized procedures recommended by the International Biological Program: Lozovina V, Pavičić L, Lozovina M. (2003). A medical balance was used with a precision of 0.1 kg, Martin anthropometer with a precision of 1 mm, pelvimeter with precision of 1 mm, skin fold caliper (John Bull) with a compression of 10 g/mm2 with accuracy of 0.1 mm, small sliding caliper with accuracy of 1 mm2, and synthetic length measuring tape with accuracy of 1 mm. Anthropometric status of subjects was determined on the basis of 23 anthropometric measures. Katch and McArdle formulae were used to estimate the body fat percentage on the basis of performed measurements: Katch FI, McArdle WD (1973).

Statistical Analysis

Data for each sample were presented as mean ± standard deviation (SD). Analysis of variance, factor analysis and discriminative analysis was used to test the differences between the two generations in manifest and latent anthropo-morphological space. SPPS statistical software, Version 11.0 (SPSS Inc., Chicago, IL, USA), was used for all statistical analyses.

Results

The two generations, 28 years apart, significantly differed in majority anthropometric measures and indices (Table 1, Fig. 1) except foot breadth, biiliocristal breadth, biepcondilar femur, wrist breadth, calf girth, sub scapular skin fold, axilar skin fold, calf skin fold, abdominal skin fold, body density and percent body fat. Comparison of length measures between the generation of 1980 and that of 2008 i.e., the leg length, total arm length, and height, showed statistically significant positive trends as well as Hand length and Foot length have significantly negative trends. Breadth measures, hand breadth and biacromial breadth, significantly decreased in the 2008 generation. The measures of soft tissues, such as girths generally increased. There were significant increases in all girths, but not significant in thigh and calf girth. In skin folds, estimators of the amount of subcutaneous adipose tissue measures of triceps and sub scapular indicate decreased trends. Abdominal, calf and axilar skin folds, shows significant increases as well as mass. Body mass index (BMI) significantly decreased. Estimated body fat percentage increased but not significantly, whereas body density remained statistically unchanged. The canonical discriminative analysis over the factor suggest: Tree factor provided significant discriminative power: factor of circular dimensionality, factor hand length and foot length and factor of longitudinal dimensionality of skeleton. In distance of 29 years water polo players mostly changed in the measures of longitudinal dimensionality in direction major values of results. Statistical significant changes arise on the hands and foots who define third factor where is noted movement in the zone of lower results. Statistical significant changes with movement in the zone of higher results were registered in all measures who defined circular dimensionality and mass. Regarding generation “80”, generation “08” is higher, heavier and stronger with relatively smaller hands and foots.

Table 2. Disriminative function

Wilks' Lambda	Chi-square	df	Sig.
.169	298.587	24	.000

Table 3. Classification Results

	Measured	Predicted Group Membership		Total
		1980	2008	
Count	1980	94	1	95
	2008	0	87	87
%	1980	98.9	1.1	100.0
	2008	.0	100.0	100.0

Table 4. Total Variance Explained

	Initial Eigenvalues	% of Variance	Cumulative %
1.00	10.32	39.67	39.67
2.00	4.75	18.26	57.93
3.00	2.19	8.43	66.36
4.00	1.54	5.93	72.29
5.00	1.31	5.04	77.33

Table 6. Component Correlation Matrix

Component	1	2	3	4	5
1	1.00	**-.38**	.01	**-.36**	**-.35**
2	-.38	1.00	-.05	.07	.11
3	.01	-.05	1.00	-.08	**-.22**
4	-.36	.07	-.08	1.00	**.37**
5	-.35	.11	-.22	.37	1.00

The Factor analysis under the component model was performed. The number retained factors were fixed by GK-criterion. After direct oblimin rotation the factor structure was calculated as well as correlations between the factors. Five factors explained 77, 33% of variability from measure system. The first factor is defined by girths and mass and it is possible to define it as circular dimensionality. Second is defined with all measures of under skin fat tissue with added body density and percent of body fat and could bee defined as subcutaneous adiposity. The third factor is defined by hand length and foot length and it is impossible to define him in morphological sense. The fourth factor is defined with hand and foot length, height and biacromial breadth. This factor is nominated as longitudinal dimensionality of skeleton. The fifth factor is defined by diameters and it is possible to proclaim him as factor of transversal dimensionality of skeleton. Correlations between factors are low what speak in one's favour that every of them exist in own sense. Correlation between first and second factor (-0, 38) is logical because treat subsumarised measures. Correlation of first factor with fourth and fifth (-0, 36 and -0, 35) probably speak about proportionality of muscular and skeletal system in water polo players.

Correlations between fourth and fifth factor (0, 37) is also logical because treat the same, skeletal system. The canonical discriminative analysis over the factor was performed. Discriminate function was calculated. Statistical significance discrimination (p=0,000) was assess wit F-test, whereas power of applied system with Wilks' Lambda.

Table 8. Eigenvalues

Eigen value	Canonical Correlation	Wilks' Lambda	Chi-square	df	Sig.
2.796	.858	.263	236.793	5	**.000**

Table 9. Classification Results

	Measured	Predicted Group Membership		Total
		1980	2008	
Count	1980	90	5	95
	2008	3	84	87
%	1980	94.7	5.3	100.0
	2008	3.4	96.6	100.0

96.6% of original grouped cases correctly classified.

Tree factor provided significant discriminative power: factor of circular dimensionality, factor hand length and foot length and factor of longitudinal dimensionality of skeleton. Canonical correlation coefficient (R=0,858) is statistically significant on the level p=0,000. Importance of discriminative function was tested with Bartett χ^2 test as well as power of applied system was tested with Wilks' Lambda. In distance of 29 years water polo players mostly changed in the measures of longitudinal dimensionality in direction major values of results. Statistical significant changes arise on the hands and foots who define third factor where is noted movement in the zone of lower results. Statistical significant changes with movement in the zone of higher results were registered in all measures who defined circular dimensionality and mass. Regarding generation "80", generation "08" is higher, heavier and stronger with relatively smaler hands and foots.

Discussion

Our study showed that body morphology and composition of male elite water polo players significantly changed from 1980 to 2008. The players measured in 2008 had longer limbs but shorter hand and smaller foot length, larger breadths with exception in biiliocristal breadth, bigger girths, less under skin fat tissue in upper body region and moor under skin fat tissue in lower body region. Their bodies are taller but more slender, with wider shoulders and thinner waist. It seems that a change in the body composition of water polo players has been accompanied by changes in the body shape. Percent of body fat and body density are unchanged, but BMI increased. There is great difference in body mass between the two generations. It seems that the body mass is achieved by the increase in the muscle and bone mass and less on account unchanged body fat. These differences maybe explained by the changes in the game of water polo and changes in environmental conditions. In 2008, water (where the game is played) has been standardized by internationally imposed norms. The playing rules of the game over the 28 years were subject to several changes. The game duration was extended, ie, almost doubled from 4×5 minutes to 4×8 minutes. Accordingly, there are less physical contacts between opponent players during the play, except centers. The ratio of vertical to horizontal posture in the water changed in favour to the horizontal one (more swimming), and there are more goal shoots: Pavičić L. (1991). Consequently, the volume and intensity of the training also considerably increased. The significantly shorter leg length, hand length and height in the 2008 generation in comparison with 1980 generation was most probably the consequence of the changes in playing conditions and rules of the game. Changes in rules of the game as it was played in 2008 promoted the use of technologically improved ball material allowing it to retain its stable characteristic for the full duration of the game. Conversely, earlier generation measured in 1980 played the game with a ball made of materials not resistant to water; consequently, the characteristics of the ball changed during the course of the game as it became heavier and its diameter larger. It seems that longer hand in the elite water polo players measured in 1980 was an advantage for better manipulation and control of the ball. The secular changes, ie, a more rapid growth and development, higher mean stature, and body mass have been noticeable in European countries and elsewhere for more than a century. Coefficients of increase in the stature per decade (cm/decade) differ among European countries, from 0.3 in Norway and Sweden to 1.9 in Slovenia: Hauspie RC, Vercauteren M, Susanne C. (1996). The average secular trend coefficient for Europe is 1.2 cm/decade. Thus, the lack of differences in body mass and a greater than expected increment in height imply some other sources of variation besides the already established population secular trend: Lozovina (2008). Due to similar training histories and psychological attributes, traits other than anthropometric characteristics contributing to success, such as skill level and physical fitness, will tend to optimize similarities among elite athletes. Given the possibilities of influencing body shape and body composition, it is obvious that anthropometric characteristics are of paramount importance for the selection and success of elite players. The observed trend can be only partially explained by a population secular trend. It is at least a twofold dynamic problem. The question on the one side is what makes a successful athlete, and on the other, how the training process and selection pressure, taken together, transform or change body characteristics of elite water polo players over time. Besides a secular trend, which is obviously present in any given population/nation: Hauspie at all (1997), Meredith (1976), elite athletes are additionally influenced by the training and selection dynamics: Mailna, 1991; Borms 1984.

The characteristic body shape and composition of successful elite athletes, in the long run, are the result of the selection process of ever changing competitive conditions in sport. Elite male water polo players have been under pressures from intensive training and selection procedures over a number of years. Hence, the sport morphological optimization/adaptation: Norton K, Olds T. (2001) must be taken into account. Regarding the types of adaptation that have occurred, it is evident from the results in our study that the body mass of elite water polo players is in the category of "absolute sports morphological optimization", whereas their height is in "open upper end optimization": Norton K, Olds T. (2001).

Secular trends in anthropometry are the result of cross-sectional studies of populations performed on many age cohorts. Furthermore, secular trend analysis and identification in particular population of the top level athletes is additionally limited by the fact that the same athletes are usually the constituents of same population for many years (7-9 years in water polo). Our study may, nevertheless, provide a good insight into the anthropometric changes in water polo players. We used multiple anthropometric variables, rarely covered to such an extent in other similar studies.

With regard to the quite large sample size of elite athletes, and especially because of range of anthropometric measures, this study is unique and may be a challenge for further investigation of the population secular trend and sport morphological optimization phenomena, with special consideration given to their possible interaction.

We believe that successful prediction of future athletes' body shape and form should be sought also in the domain of complex systems theory: Katch FI, McArdle WD (1973), Forrester JW. (1992), Waldrop M. (1992), Kauffman SA (1993), Holland JH (1986). Anthropometric characteristics of elite water polo players have changed over the analyzed 28 years. Body shape changed in terms of greater height and more elongated limbs, with thinner waist and broader shoulders. Body mass increased. Muscle to fat-mass ratio increased. The factor and canonical discriminative analysis results suggest that morphological changes arise in 28 yare periods. Five factors in latent space were identified and define as: circular dimensionality of skeleton, under skin fat tissue, hand and foot length, longitudinal dimensionality of skeleton and transversal dimensionality of skeleton. Significant and greatest discrimination in morphological structure between generations 80" and 08" make longitudinal dimensionality, circular dimensionality and in some slight degree factor hand length and foot length. There are no significant changes between generations in transversal dimensionality of skeleton and under skin fat tissue.

Conclusion

Anthropometric characteristics of elite water polo players have changed over the analyzed 28 years. Body shape changed in terms of greater height and more elongated limbs, with thinner waist and broader shoulders. Body mass increased. Muscle-to-fat mass ratio increased. The observed changes are consequence of population secular trend and sport morphological adaptation (optimization).

Table 1. Tests of Equality of Group Means, Group Statistics

	2008y	1980y			
	Mean	Std. Deviation	F	Sig.	Discr.Funct.Structure
leg length	1085.368±48.180	1056.295±41.773	19.00	.00	.15
total arm length	856.655±35.909	802.883±30.908	117.77	.00	.36
hand length	191.885±8.257	200.310±8.922	43.47	.00	-.22
foot length	275.448±14.121	280.487±10.998	7.28	.01	-.09
height	1924.724±63.789	1858.551±52.654	58.63	.00	.26
hand breadth	88.885±3.571	81.906±5.612	98.13	.00	.33
foot breadth	102.874±5.164	102.842±6.170	.00	.97	.00
biacromial breadth	440.000±19.707	420.606±19.497	44.47	.00	.22
biiliocristal breadth	295.287±19.579	297.092±14.913	.49	.48	-.02
biepcondilar femur	100.253±4.601	99.340±5.191	1.56	.21	.04
biepycondilar humerus	74.184±3.684	73.101±3.405	4.25	.04	.07
wrist breadth	61.345±3.034	60.587±2.835	3.04	.08	.06
chest girth	1092.816±66.292	1030.507±45.463	55.46	.00	.25
arm girth	347.931±21.940	328.262±20.804	38.53	.00	.21
forearm girth	295.000±13.534	282.083±11.404	48.75	.00	.23
thigh girth	618.264±41.690	601.316±28.247	10.46	.00	.11
calf girth	392.402±23.523	389.141±15.903	1.22	.27	.04
triceps skin fold	8.170±2.624	9.252±2.759	7.32	.01	-.09
subscapular skin fold	10.901±3.550	10.970±3.171	.02	.89	.00
axilar skin fold	9.208±4.486	9.053±3.656	.07	.80	.01
calf skin fold	8.692±3.568	7.966±2.151	2.81	.10	.06
abdominal skin fold	14.303±6.447	13.431±5.560	.96	.33	.03
weight	947.586±111.626	851.663±72.470	48.05	.00	.23
body mass index	25.521±2.083	24.647±1.707	9.67	.00	.10
body density	1.074±.007	1.074±.007	.44	.51	.02
percent body fat	10.794±3.051	11.087±2.992	.43	.51	-.02

N (80)= 95, N (08)= 87, df1=1,df2=180

Table 5. Factor analysis, Direct Oblimin

	Pattern					Structure					
	1	2	3	4	5	1	2	3	4	5	Communalities
leg length	-.17	-.09	.20	-.87	-.12	.22	-.11	.30	-.88	-.43	.847
total arm length	.05	.04	.03	-.88	-.04	.36	-.05	.10	-.91	-.38	.836
hand length	.01	.07	.86	-.10	.08	.01	.02	.85	-.14	-.14	.740
foot length	-.06	.02	.71	-.21	-.29	.11	-.03	.78	-.35	-.49	.760
height	.00	-.02	.11	-.86	-.16	.37	-.11	.21	-.93	-.50	.906
hand breadth	.13	.06	-.48	-.31	-.61	.42	-.05	-.33	-.54	-.66	.778
foot breadth	-.05	.08	.11	-.04	-.76	.21	.01	.27	-.31	-.78	*.629*
biacromial breadth	.39	.12	-.04	-.53	.05	.52	-.06	-.01	-.64	-.26	*.529*
biiliocristal breadth	.28	-.24	.48	-.15	-.10	.46	-.39	.52	-.34	-.38	*.559*
biepcondilar femur	.02	-.21	-.04	.02	-.80	.37	-.30	.14	-.29	-.81	.713
biepycondilar humerus	.17	-.01	.11	-.20	-.54	.44	-.15	.25	-.47	-.70	*.576*
wrist breadth	.12	.03	.03	.00	-.72	.35	-.09	.19	-.30	-.76	*.592*
chest girth	.68	-.16	-.11	-.37	.05	.85	-.43	-.07	-.60	-.31	.861
arm girth	.79	-.14	-.14	-.12	-.02	.89	-.44	-.11	-.41	-.32	.838
forearm girth	.77	.04	-.10	-.16	-.16	.87	-.28	-.05	-.48	-.46	.814
thigh girth	.71	-.31	.08	-.04	-.04	.85	-.59	.12	-.34	-.35	.822
calf girth	.73	.09	.25	.24	-.28	.71	-.21	.29	-.14	-.49	.678
triceps skin fold	-.17	-.86	.15	.16	-.12	.14	-.80	.20	.10	-.12	.724
subscapular skin fold	.11	-.89	-.04	.02	.02	.43	-.92	.00	-.08	-.10	.864
axilar skin fold	.14	-.85	-.03	-.05	.16	.43	-.89	-.02	-.10	.01	.824
calf skin fold	-.02	-.70	-.09	-.05	-.14	.31	-.71	-.02	-.14	-.21	*.531*
abdominal skin fold	.16	-.84	-.07	-.13	.11	.48	-.89	-.04	-.20	-.07	.840
weight	.63	-.15	.07	-.42	-.09	.87	-.43	.14	-.70	-.49	.956
body mass index	.92	-.19	.01	.16	.01	.93	-.53	.01	-.18	-.27	.925
body density	-.03	.98	-.02	-.01	-.01	-.40	.99	-.06	.07	.11	.981
percent body fat	.03	-.98	.02	.01	.01	.40	-.99	.06	-.07	-.11	.981

Table 7. Group Statistics, F-test of differences, disciriminative function structure

	1980		2008		Wilks' Lambda	F	Sig.	Discr. Funct. Struct.
	Mean	Std. Deviation	Mean	Std. Deviation				
Circular dimensionality	-.347	.780	.379	1.078	.868	27.357	**.000**	**-.233**
Subcutaneous adiposity	-.041	.959	.045	1.047	.998	.334	.564	-.026
Hand and foot length	.510	.810	-.557	.886	.714	72.142	**.000**	**.379**
Longitudinal dimensionality	.570	.728	-.622	.881	.644	99.573	**.000**	**.445**
Transversal dimensionality	.128	1.047	-.139	.932	.982	3.283	.072	.081

df1=1, df2=180

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PROMJENE U MORFOLOGIJI KOD ELITNIH VATERPOLISTA: ISTRAŽIVANJE U 1980. I 2008.

Sažetak

Usporedba između antropometrijskih mjera dviju generacija vaterpolista otkrila je pozitivan trend u dijelu skeletnih mjera (dužina ruke, širina šake, visina i biacromialni raspon) i negativan trend kod dužine šake.Pozitivan trend zabilježen je u mjerama cirkularne dimenzionalnosti (opsegu grudi, opsegu podlaktice i opsegu nadlaktice) kao i u masi tijela. Najveće razlike u smislu porasta zabilježene su kod dužine ruke, visine i širine šake odnosno u smislu pada vrijednosti kod dužine šake. Navedene varijable statistički signifikantno diskriminiraju generaciju "08" od generacije"80"u manifestnom prostoru antropometrijskih varijabli. U latentnom prostoru tri od pet faktora diskriminira dvije generacije. Iz diskriminativne faktorske strukture vidljivo je da faktor longitudinalne dimenzionalnosti skeleta ima najveću razlikovnu moć. Slabije, ali značajno, grupe diskriminira treći faktor definiran dužinom ruke i dužinom stopala s pridodanim biiliocristalnim rasponom, negativnog predznaka. Manju, ali značajna diskriminativna moć negativnog predznaka ima faktor definiran mjerama cirkularne dimenzionalnosti s pridodanom težinom i body mass indeksom. Antropometrijska obilježja elitnih vaterpolisti su se promijenile tijekom analiziranih 28 godina. Oblik tijela promijenio u smislu veće visine, više izduženih udova, tanjeg struka i širih ramena. Mase tijela se povećala. Omjer između mišićne mase i masti pokazuje porast. Zapažene promjene posljedica su sekularnog trenda populacije, jednim dijelom i sportsko-morfološke adaptacije (optimizacija), drugim dijelom.

Ključne riječi: *antropometrija, morfologija, vježbe, vaterpolo, sportska medicina*

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Correspondence to:
Assist.Prof.Mislav Lozovina, Ph.D.
University of Split
Faculty for Maritime studies
21000 Split, Domovinskog rata 8, Croatia
Phone: +985 (0)21 393 500
E-mail: lozovina@pfst.hr