FACTOR ANALYSIS OF ANTHROPOMETRIC CHARACTERISTICS IN YOUNG SWIMMERS AGED 11 AND 12

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The aim of this study was to describe the set of somatic characteristics, which significantly discriminate young swimmers. The factor analysis let us reduce the number of somatic traits mostly correlated and to calculate the main structural factors typical for young swimmers. There were 80 pupils (11 and 12 years old) from the primary sport school in Wroclaw recruited for the study. The participants selected for the study had been involved in swimming for 2–3 years. On average their training time was 12 to 18 hours per week. The following parameters were established: body height and weight, upper and lower extremities' length, circumferences of: the thigh, shank, arm, forearm, chest at rest, chest after inspiration, chest after expiration, waist, hips, shoulder width, hips' width, chest width, chest depth, and Rohrer index. All data were normalised at mean and standard deviation to join all children in one group. In order to accomplish the aim of the study, a factor analysis method was employed. Analysis of the results indicated that only some traits, from among all data, are characteristic for young swimmers. They are connected into two somatic factors: the cubic content (including body weight, muscles, trunk and upper and lower extremities' circumferences), vertical dimension (including body height and upper and lower extremities' lengths). Those parameters indicate formation of the body figure typical for swimmers, characterised by specific proportions of the body's weight and height, chest and hips, and usually by longer limbs. Results suggest those somatic parameters characterising young swimmers in the best way. They should be used in a training process' estimation and a check-up of after training changes, as well as sport selection.

Keywords: Young swimmers' morphology, somatic features of young swimmers, factor analysis, swimming sport and body morphology.

INTRODUCTION

Movement is one of the basic symptoms of life. Thus, motion activity has accompanied human beings from their conception. Remaining in a close relationship with motion activity during our life we don't think about its essence. This point of view appears only in special situations, when a specific motion form becomes a desirable value, e.g. during practising sport (Szopa et al., 1996). Monitoring of the influence of an increased movement dose on children's organisms in their progressive development phase justifies multidirectional changes which can occur in the young organism (Benefice et al., 1990; Courteix et al., 1997).

Facts of the biological after-effects of over-training such as ossification of the epiphysis cartilage, hindering the body's growth, are widely known (Ohlen et al., 1989; Stager et al., 1984; Bencke et al., 2002). On the other hand, some people are more susceptible to the disadvantageous influence of training. In the face of this fact, selection is very important (Leone et al., 2002).

Training is a very strong stimulus affecting an organism's status. It must be remembered that during its development, the organism is rebuilt in a direction which will be imposed by physical exercises. Crossing functional adaptation borders can lead to biological equilibrium upset and to developmental irregularities or disproportion.

A child's organism can develop in one direction, e.g. excessive increase in muscle mass at the cost of impairment of traits such as height or organism function. In extreme cases, excessive exploitation of children's biological strength can lead to a change in the rate of sexual maturation.

In sport practice various forms of selection for practising sport occur, such as natural selection, intuitive selection, and guided selection.

All actions connected with children and youth in sport should take into account aspects of biological development. A prognosis of the development of functional abilities should be made on the basis of development parameters depending on training practice. The basis for foresight of development abilities and selection should be stable features (Duche, 1993). Those are features determined by hereditary factors as well as inborn abilities. At the beginning of training the high level of these factors determine the achievement of mastery in the future. Height and maximal work capacity (VO_2max) should be mentioned.

The most significant changes resulting from physical activity occur in the body build and in the muscular system (Lowensteyn et al., 1994; Mosaiger et al., 1994; Roemmich & Sinning, 1996; Kozlowski & Nazar, 1996). Sometimes development of muscles takes place at the cost of development of other features, such as body height and its functions.

There are two important elements in the training process: selection at the beginning and supervision during training. Good, proper selection allows us to choose some talented persons with the somatic and functional predisposition to any kind of sport discipline. Good supervision of the morphofunctional development of children decreases the risk of negative changes in their organism. The problem is what kind of somatic and functional traits should be observed. The coach, instructor or medical doctor has very often a dilemma as to which parameters should be chosen. The choice is very often based on intuition. Consequently a group of accidental, strongly correlated parameters are usually chosen. On the other hand, taking into account a wide range of measurements and time-consuming examinations, looking for parameters' models describing typical sport morphology is strongly recommended.

The aim of the work was to describe correlations between somatic parameters, their interactions and identification factors completely characterising the body morphology of young swimmers.

MATERIALS AND METHODS

The research on some morphological traits of school children was done on the population of 80 pupils from a designated primary sport school in Wroclaw.

The research group consisted of 11 year and 12 year old pupils attending the 5th and 6th class of the Primary school number 72 in Wroclaw. The group of boys aged 11 contained children from 10.51 to 11.50 (mean = 11.04, sd = 0.29). The group of boys aged 12 contained children from 11.51 to 12.50 (mean = 12.06, sd = 0.27). Such methodology of qualification into groups relates to girls, too (11 years old: mean = 11.11, sd = 0.22; 12 years old: mean = 12.09, sd = 0.27). All of the pupils under investigation have been members of the swimmer clubs Śląsk and Juvenia in Wroclaw for 2–3 years. The children spend, on average, from 12 to 18 hours a week in the swimming pool.

In our research we employed the following measurements: circumferences, width, length recorded in centimetres (cm), age (years), weight (kg), height (cm) and gender were recorded. Namely, 18 body dimensions were considered, including:

body height,
body weight,
upper extremity length (a-da_{III}) – the average of right and left lengths,
lower extremity length (B-sy) – from the pubic symphysis to the base,
thigh (maximum) circumference,
calf (maximum) circumference,
arm (maximum) circumference (biceps circumference, flexed),
forearm (maximum) circumference (extended, palm up),
chest circumference – rest – nipple line in males and just above the breast tissue in females,
chest circumference – inspiration – nipple line in males and just above the breast tissue in females,
chest circumference – expiration – nipple line in males and just above the breast tissue in females,
waist circumference,
hip circumference,
shoulder width – diameter (a-a),
hip width – iliocristal diameter (ic-ic),
chest width – (thl-thl),
chest depth – antero-posterior chest (xi-xi).

Obtained values were used to calculate Rohrer index:

$$\text{Rohrer index} = \frac{\text{body weight (g)}}{(\text{body height})^3} \times 100$$

Body parameters have been measured in accordance with the method of Martin and Saller.

The next statistical analysis of the collected data was carried out. Age groups of the children were connected in order to increase the number of observations, which enabled the use of proper statistical methods. According to principles, data has been normalised with respect to mean and standard deviations for the appropriate age group.

In this way, the influence of age on the diversity of body build was cancelled, which allowed us to join together older and younger children's groups.

This formula was used (Stanisz, 1998):

$$Z = \frac{Xi - \bar{x}}{SD}$$

Z – normalised value; Xi – value of the measured parameter (for the child); $\bar{x}$ – mean value of a given parameter in the age group of the child; SD – standard deviation of parameters according to the age group of the child.

Next, base statistical parameters such as the arithmetic mean, standard deviation, minimal and maximal values of body dimensions were calculated. Also a simple Pearson correlation between all parameters was calculated. Finally the main somatic factors were calculated based on factor analysis. The factor analysis method applied in this research was used to determine the groups of parameters (factors) characterising the body constitution of young swimmers. We used the main factors method with Varimax rotation. This orthogonal rotation procedure improves the factors' structure. It causes the highest degree of variances of the factors (Stanisz, 1998).

RESULTS

Arithmetic means, standard deviations, minimal and maximal values of absolute and normalised body dimensions are presented in TABLES 1–3.

The factor analysis method was used to reduce the group of data. It's a popular method in anthropology and kinesiology (Ohlen et al., 1989). First we analysed the strength of the correlation between all somatic traits (TABLE 4). The strong links between somatic parameters suggest the rightness of the hypothesis that the set of data is too broad and could be reduced to those describing the morphology of body build parameters. The closest correlation (an over 0.9 coefficient) was observed in all three chest measurements.

In TABLE 5 of self values, variance of each principal component, are presented. Two of the self-values obtained indicate the presence of only two logically and reasonably descriptive morphological builds of swimmers. These values, especially the first principal component, are significant (Ostrowska et al., 2000; Skibinska et al., 1988). The "scree chart" (Fig. 1) proves the rightness of the analysis based only on two of the components mentioned above.

TABLE 1
Absolute values of somatic parameters of the 11 and 12 years old boys

Years	11				12			
Parameter	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Body height	154.55	7.80	141.00	174.00	156.00	7.78	143.00	170.00
Body weight	44.17	8.10	32.00	59.00	43.48	8.47	30.00	63.50
Rohrer index	1.19	0.12	0.97	1.41	1.14	0.13	0.87	1.33
Upper limb (arm) length	68.88	4.59	62.00	80.50	71.93	5.62	66.00	87.00
Lower limb (leg) length	83.50	5.46	74.00	97.50	84.23	4.79	77.00	93.00
Thigh circumference	48.63	4.99	41.00	59.00	46.70	4.40	40.00	56.00
Calf circumference	30.68	2.70	26.00	36.00	30.18	3.32	20.00	34.50
Arm circumference	25.03	2.46	22.00	29.00	24.35	3.17	17.00	30.50
Forearm circumference	22.10	2.13	18.00	26.00	21.93	2.28	17.50	26.50
Chest circumference – rest	74.33	6.15	66.00	86.00	74.45	6.47	63.00	89.00
Chest circumference inspir.	78.85	5.50	72.50	89.00	78.75	6.74	70.00	96.00
Chest circumference expir.	72.55	6.33	64.50	85.00	72.75	6.71	60.00	88.00
Waist circumference	66.70	6.25	55.00	77.00	65.18	5.38	55.50	76.50
Hip circumference	78.93	6.15	69.50	89.00	78.53	5.45	70.00	87.50
Shoulder width	34.58	2.24	31.50	40.00	34.15	3.91	29.00	43.00
Hip width	24.50	2.04	21.00	29.00	24.20	1.78	21.00	28.00
Chest width	24.23	1.93	21.00	28.00	26.03	3.01	22.00	34.00
Chest depth	16.23	2.98	12.00	22.00	16.13	3.86	11.00	24.00

TABLE 2
Absolute values of somatic parameters of the 11 and 12 years old girls

Years	11				12			
Parameter	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Body height	151.50	6.17	143.00	165.00	159.45	7.75	147.00	179.00
Body weight	40.61	6.75	29.50	52.00	47.15	8.48	32.00	62.50
Rohrer index	1.16	0.11	1.01	1.41	1.16	0.16	0.92	1.53
Upper limb (arm) length	67.23	3.10	62.00	73.00	71.30	3.93	62.50	78.00
Lower limb (leg) length	80.98	4.37	68.00	88.50	87.00	3.80	78.50	96.00
Thigh circumference	48.38	4.17	42.00	58.00	50.70	5.80	41.50	60.00
Calf circumference	29.75	2.10	26.00	33.50	31.48	3.05	25.50	37.00
Arm circumference	23.15	2.34	19.00	27.50	24.28	2.72	19.50	29.00
Forearm circumference	20.95	1.83	18.00	24.00	21.65	1.89	18.00	25.00
Chest circumference – rest	72.40	3.92	65.00	82.00	73.75	7.07	60.00	84.00
Chest circumference inspir.	75.80	4.07	70.00	84.00	78.28	6.18	67.00	88.00
Chest circumference expir.	70.83	4.56	63.50	84.00	71.55	6.90	59.00	81.00
Waist circumference	62.63	4.72	54.00	73.00	65.53	5.17	57.00	76.50
Hip circumference	77.03	5.27	68.00	88.00	83.85	7.55	72.50	98.00
Shoulder width	33.45	2.44	30.00	38.00	34.90	2.47	31.00	40.00
Hip width	23.25	2.34	20.00	28.00	25.30	2.48	21.00	30.00
Chest width	24.20	1.46	21.00	28.00	25.15	1.79	21.50	28.00
Chest depth	14.65	2.58	12.00	20.00	17.33	3.16	12.00	21.00

TABLE 3
Normalised values of somatic parameters

Parameter	Mean	SD	Min	Max
Body height	0.04	0.93	–1.68	2.30
Body weight	–0.12	0.86	–1.57	1.94
Rohrer index	–0.23	0.77	–2.03	1.27
Upper limb (arm) length	0.31	1.19	–1.59	4.05
Lower limb (leg) length	–0.02	1.01	–1.98	2.69
Thigh circumference	0.01	0.85	–1.36	2.04
Calf circumference	–0.28	0.81	–3.10	1.22
Arm circumference	0.21	0.98	–2.46	2.23
Forearm circumference	0.22	1.03	–1.92	2.35
Chest circumference – rest	0.04	0.82	–1.46	1.96
Chest circumference inspir.	0.03	0.81	–1.14	2.32
Chest circumference expir.	0.05	0.86	–1.63	2.10
Waist circumference	0.04	0.70	–1.28	1.37
Hip circumference	–0.21	0.71	–1.35	1.06
Shoulder width	0.18	1.14	–1.77	3.31
Hip width	0.20	0.81	–1.24	2.20
Chest width	0.08	1.20	–1.78	4.09
Chest depth	–0.38	1.13	–2.09	2.21

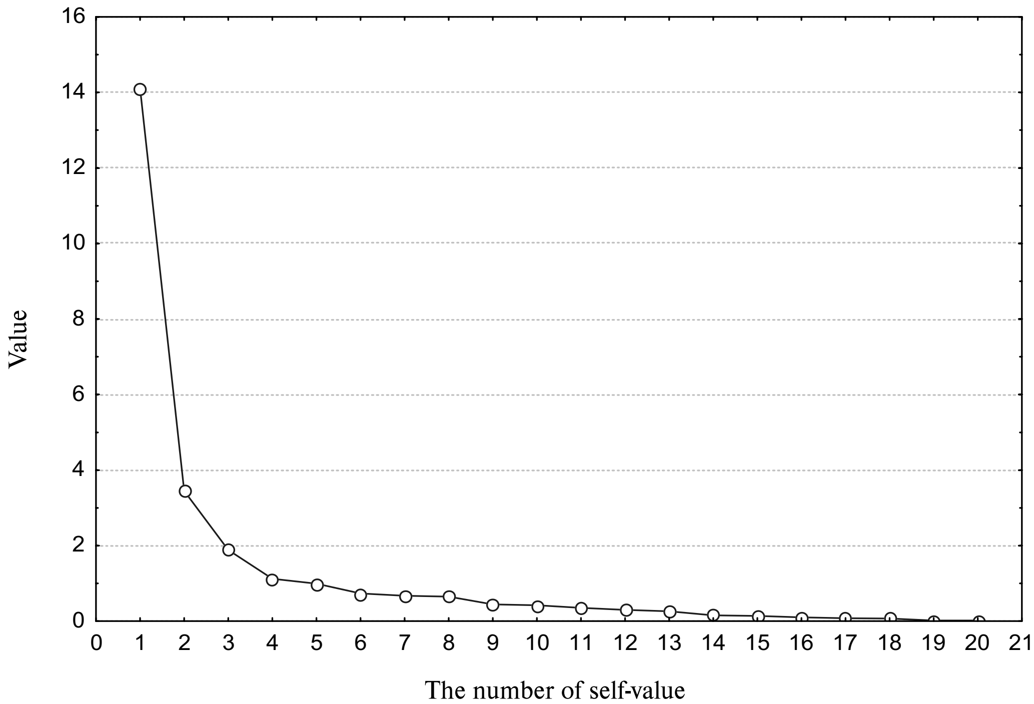
TABLE 4
Correlation between all parameters

	Body height	**Body weight**	**Rohrer index**	**Upper limb length**	**Lower limb length**	**Thigh circumf.**	**Calf circumf.**	**Arm circumf.**	**Forearm circumf.**	**Chest circumf.--rest**	**Chest circumf. inspirat.**	**Chest circumf. expirat.**	**Waist circumf.**	**Hip circumf.**	**Shoulder width**	**Hip width**	**Chest width**
Body weight	0.74																
Rohrer index	–0.03	0.64															
Upper limb (arm) length	0.79	0.61	0.02														
Lower limb (leg) length	0.78	0.51	–0.12	0.74													
Thigh circumf.	0.54	0.74	0.48	0.43	0.40												
Calf circumf.	0.54	0.79	0.55	0.42	0.39	0.69											
Arm circumf.	0.52	0.82	0.63	0.47	0.29	0.80	0.76										
Forearm circumf.	0.52	0.80	0.59	0.52	0.28	0.73	0.72	0.89									
Chest circ.-rest	0.55	0.85	0.62	0.47	0.31	0.75	0.75	0.87	0.80								
Chest circ.-inspir.	0.53	0.81	0.59	0.45	0.30	0.69	0.73	0.80	0.77	0.93							
Chest circ.-expiration	0.56	0.84	0.61	0.46	0.32	0.75	0.75	0.86	0.80	0.99	0.93						
Waist circumf.	0.45	0.80	0.67	0.39	0.27	0.70	0.75	0.85	0.77	0.86	0.83	0.84					
Hip circumf.	0.65	0.85	0.52	0.56	0.51	0.77	0.79	0.80	0.73	0.84	0.80	0.84	0.82				
Shoulder width	0.64	0.70	0.33	0.67	0.50	0.61	0.56	0.69	0.73	0.67	0.64	0.67	0.56	0.66			
Hip width	0.49	0.54	0.25	0.42	0.46	0.53	0.53	0.47	0.45	0.49	0.46	0.49	0.52	0.64	0.52		
Chest width	0.48	0.67	0.44	0.49	0.29	0.55	0.60	0.64	0.62	0.71	0.69	0,69	0.67	0.65	0.61	0.46	
Chest depth	0.29	0.53	0.45	0.19	0.30	0.37	0.53	0.42	0.37	0.52	0.52	0.51	0.53	0.58	0.25	0.33	0.46

TABLE 5
Self-values of the principal components

	Self-values	Percent of the all variance	Cumulated self-values	Cumulated percent
Factor 1	13.24	52.95	13.24	52.95
Factor 2	3.45	13.78	16.68	66.73

Fig. 1
"Scree chart" with values of all factors



The first factor identifies about 53% of variability in the group of analysed parameters. The second factor identifies more variability. Its value was about 67%.

Good representation of the original basic correlation matrix between parameters was shown by remnant correlation (disparity between correlation coefficients in the input matrix and correlation calculated on the base of factors' values).

Disparities mentioned above were not significant thus the swimmer's body built described by two separated components is satisfactory.

In the next step the factor's structure – factors linked with input data – was defined by means of correlation of the parameters given with the factor. Due to the description of factors, factor loads were calculated (correlation of separated factors with original data). First factor loads without system rotation were calculated (before optimalisation – factor loads strength increase). The varimax rotation was applied to factor structure improvement (TABLE 6).

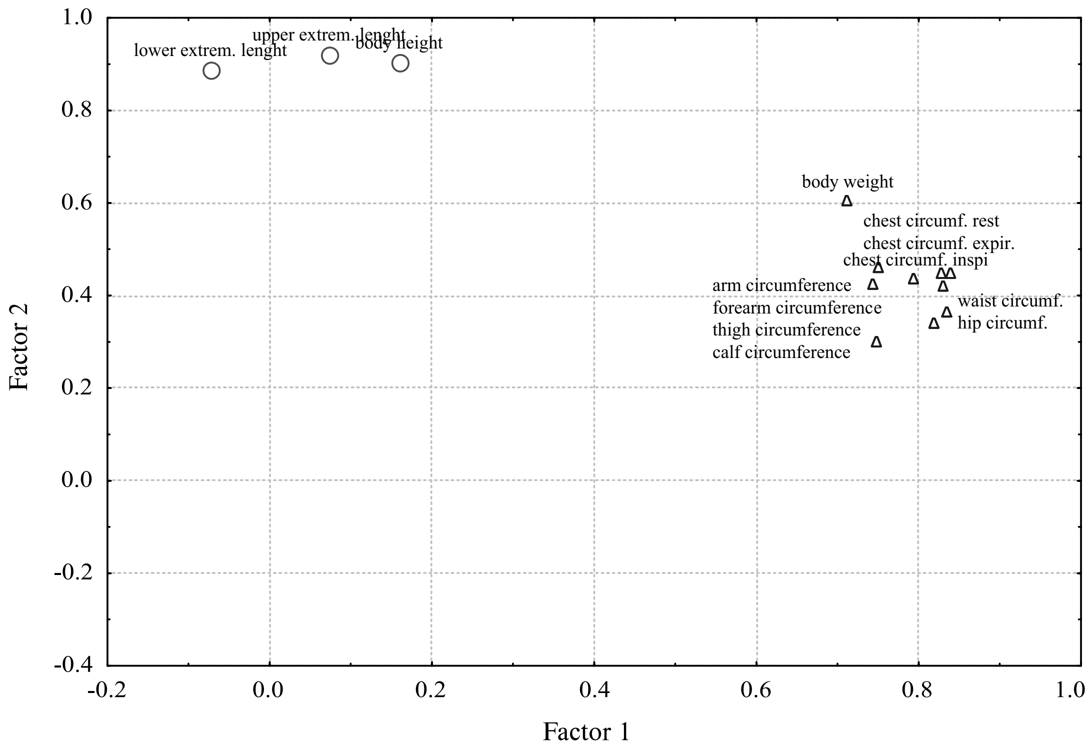
Factor 1 is a combination of: body weight, Rohrer index, circumferences of the calf, forearm, chest, waist and extremities. This factor was called cubic content. It describes body morphology of swimmers better than factor 2 what is proved by previously described values and the percentage of variability explained.

Factor 2 is a combination of three parameters: body height, upper and lower extremity length. All those traits are length parameters indicating vertical values of the entire body. This factor was called vertical dimension. Fig. 2 illustrates factors' structure.

TABLE 6
Factorial load values after Varimax rotation (statistically significant factor loads are bold)

	Factor 1	**Factor 2**
Body height	0.16	**0.90**
Body weight	**0.71**	0.60
Rohrer index	**0.88**	–0.13
Upper limb (arm) length	0.07	**0.92**
Lower limb (leg) length	–0.07	**0.89**
Thigh circumference	0.67	0.48
Calf circumference	**0.75**	0.42
Arm circumference	**0.83**	0.42
Forearm circumference	**0.75**	0.46
Chest circumference – rest	**0.84**	0.45
Chest circumference inspiration	**0.80**	0.43
Chest circumference expiration	**0.83**	0.45
Waist circumference	**0.84**	0.36
Hip circumference	0.69	0.60
Shoulder width	0.45	0.69
Hip width	0.36	0.55
Chest width	0.59	0.48
Chest depth	0.52	0.24

Fig. 2
Factors' structure after Varimax rotation



DISCUSSION

Beneficial effects of intense physical activity have been described by lots of authors who emphasise that swimming is a form of a physical activity having a positive influence on the cardiovascular and respiratory systems (Dziedziczak & Witkowski, 1988; Ostrowska et al., 2001). A young body is flexible and susceptible to various stimuli, which exceed the limits of biological tolerance of the body and are inadequate for the level of development of somatic and motor capacities of a child, and may affect the processes of body growth and maturation. Numerous studies carried out on groups of young sportsmen engaged in various sport disciplines (swimming, gymnastics, team games, tennis, etc.) show divergent views concerning the impact of high-performance sports on physical development and the age, when the body becomes mature (Baxter-Jones et al., 1995). It has been proved that among sportsmen, who began training in the pre-puberty period, swimmers show the most rapid development of sex characteristics. It applies to both boys and girls (Malina et al., 1982; Damsgaard et al., 2001). However, the majority of authors report that swimming training does not disturb the puberty period (Courteix et al., 1997) and does not inhibit physical development (Baxter-Jones et al., 1995), including height increase, which, to a large degree, is dependent on the genetic traits inherited from their parents (Malina et al., 1982).

The issue of a proper selection of children and youth for high-performance sports training has been studied by many authors (Bartkowiak, 1988; Łaska-Mierzejewska et al., 1985; Piechaczek et al., 1995). The main point here is the age at which the training has begun and defining the criteria, which allow us to confirm the suitability of candidates for a specific sport discipline based on their individual somatic features, motor skills, physical fitness, and other characteristics (Knop, 1996). Somatic features are an important factor conditioning an achievement in sports (Siders et al., 1993) and are one of the elements taken into consideration during the candidate selection process. The method of factor analysis used in our studies allowed, selecting from a large set of somatic features, only two groups of features demonstrating the most significant discriminating power for swimmers (Łaska-Mierzejewska, 1980; Ohlen et al., 1989). Although changing of these parameters may be an effect of training changes, the selection effect cannot be excluded.

In general, the results obtained by many authors show higher values of height and weight of children training (Ostrowska et al., 2001; Courteix et al., 1997; Benefice et al., 1990; Duche et al., 1993). The results of our studies only partially confirmed these observations. Because basic somatic traits are on the basis of two factors. These factors we called vertical dimension and cubic content, suggesting that the most important in swimming sport are length parameters connected with a better range of swimming movements in the pool and cubature (including body weight, muscles and chest circumferences), indirectly informing about vital capacity and circular-respiratory system efficiency.

CONCLUSIONS

1. The method of factor analysis is an efficient tool for characterising somatic parameters among swimmer children.
2. The analysis of 18 somatic parameters allows us to separate two factors of body morphology:
   a) the cubic content (including body weight, muscles, trunk and upper and lower extremities circumferences),
   b) vertical dimension (including body height and upper and lower extremities' lengths).
3. These traits should be used in training process estimation and check-up after training changes, as well as sport selection.

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FAKTOROVÁ ANALÝZA ANTROPOMETRICKÝCH CHARAKTERISTIK U MLADÝCH PLAVCŮ VE VĚKU 11 A 12 LET

(Souhrn anglického textu)

Cílem této práce bylo popsat vybrané somatické charakteristiky typické pro mladé plavce. Faktorová analýza umožnila úměrné snížení somatických ukazatelů a umožnila vypočítat hlavní strukturální faktory typické pro mladé plavce. Do výzkumného souboru bylo zařazeno 80 žáků (11 a 12letých) přijatých ke studiu na základní sportovní škole ve Wroclawi. Sledovaní probandi trénovali po dobu 2–3 let a jejich průměrný tréninkový čas byl 12 až 18 hodin týdně. Byly měřeny následující parametry: tělesná výška a hmotnost, délka horních a dolních končetin, obvod stehen, lýtka, paží, předloktí, hrudníku v klidu, hrudníku po nádechu a po výdechu, obvod pasu a boků, šířka ramen, šířka boků, šířka hrudníku, hloubka hrudníku a Rohrerův index. K dosažení cíle této studie byla použita metoda faktorové analýzy. Analýza výsledků ukázala, že pouze některé zvláštnosti mezi sledovanými parametry jsou pro mladé plavce charakteristické. Jsou spojeny do 2 trsů somatických charakteristik: kubický obsah (zahrnuje tělesnou hmotnost, svalstvo, trup a obvod horních a dolních končetin) a vertikální rozměr (zahrnuje tělesnou výšku a délku horních a dolních končetin). Tyto parametry signalizují formování postavy typické pro plavce, charakteristické specifickými proporcemi tělesné hmotnosti a výšky, hrudníku a boků a obvykle delšími končetinami. Výsledky naznačují, že antropometrické charakteristiky

lze použít pro optimalizaci tréninkového procesu mladých plavců.

Klíčová slova: morfologie, somatické rysy, faktorová analýza, plavání.

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