USE OF DIFFERENT METHODS FOR TESTING MORPHOLOGICAL CHARACTERISTICS AND EVALUATION OF BODY TISSUE COMPOSITION OF SWIMMERS

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Abstract. Specific characteristics of sport disciplines require their performers to meet certain demands, also those related to body build. A success is conditioned, among other things, by the morphological structure of competitors. For this cause, their somatic features should be taken into consideration in the selection process. The aim of this research was to describe the level of morphological development and body proportions of swimmers in comparison to their non-practicing peers. What is more, different methods were used to evaluate body tissue composition. The research was based on the measurements of 33 swimmers and 36 non-practicing sport males as a control group, with the average training period of 9 years. The subjects ranged from 18 to 23 years of age. The anthropometric features were examined. Two methods, anthropometric and bioelectrical impedance, were used to estimate the amount of body fat. Athletes performing swimming are characterized by the significant body height, long trunk, wide range of arms and highly developed shoulder girdle. Directed and systematic training has an influence on a great development of the upper part of the trunk and a slight decrease in body fat. The observed differences indicate that depth, circumference and mobility of the chest developed in swimming have a positive influence on the respiratory system.
Poor differences observed in the amount of fat in the athletes and non-practicing subjects may result from the fact that the body accumulates fat tissue, used as a good thermal insulation.

Key words: body proportion, body composition, swimmers

Introduction

Specific characteristics of sport disciplines require their performers to meet certain demands, also those related to body build. A success is conditioned, among other things, by morphological structure of competitors. For this cause, their somatic features should be taken into consideration in the selection process. Suitable morphological predispositions, essential in a given sports discipline, are later reinforced by the application of special training. Hence, evaluation of anthropometric measurements, in reference to their non-sport practicing peers, enables to create morphological models optimal for a selected sport discipline. Moreover, it creates an opportunity to decide which type of physical effort modifies selected measurement features (Drozdowski 1984; Wieczorek 2001).

Swimming is considered to be a sport shaping all motor abilities, which improves general health and body condition (Czabański and Fiłon 1994). Research conducted by Pietraszewska has revealed similar body build in athletes practicing swimming regularly, confirmed by a poor inter-individual somatic diversification (Pietraszewska 1998). Research on swimmers' body composition has revealed that, in comparison to a control group, they are characterized by a decrease of fatness and increase of lean body mass in the upper part of the trunk and upper extremities (Avlonitou et al. 1997). Morphological shape of a swimmer's body is conditioned at each phase of their training, based on specific exercises in the water environment (Bartkowiak 1999). Swimming coaches select well-proportioned, tall and slim children who have not yet visibly developed their muscles, and are characterized by narrow pedicle of bones and large hands and feet. One of the selection criterion is parent's body height, on the basis of which one is able to predict final body height of a competitor (Sachnowski et al. 2005). According to Sachnowski et al. (2005), the analysis of morphological and functional conditioning in children may enable a coach to direct a future competitor to a certain swimming style. Hence, children with long limbs and wide shoulders should specialize in a short-distance freestyle swimming, while those with good swimming skills, aerodynamic body, narrow hips and increased joints mobility should become long-distance competitors.

The types of selection described hereinabove and the influence of specific training lead to a better morphological and functional adaptation of the experienced athletes to perform swimming. Occasionally, athletes specializing in the same type of swimming may reveal differences in anthropometric features depending on their level of qualification, applied set of measurement features and the research tools used.

The aim of this research was to describe the level of morphological development and body proportions of swimmers in comparison to their non-practicing peers. In order to achieve that premise, different methods were used to evaluate body tissue composition.

Material and methods

The research was based on the anthropometric measurements of 33 swimmers and 36 non-practicing sport males as a control group, with the average training period of 9 years. The subjects ranged from 18 to 23 years of age.

The following somatic features were measured: body height (B-v), trunk length (sst-sy), upper extremity length (a-daIII), lower extremity length (B-sy), lower leg length (B-ti), bidactylion diameter – span (da III-da IIII), biacromial diameter (a-a), biacromial diameter (dl-dl), chest diameter (thl-thl), chest depth (xi-ths), biiloicristal diameter (ic-ic), distantia intertrochanterica (tro-tro), foot length (pte-ap), foot breadth (mtt-mtf), elbow breadth (cl-cm), knee breadth (epl-epm).

The circumference of the following body parts was measured: neck, shoulder girdle, chest at rest, chest at maximum inhalation and exhalation, chest at rest through ix point, chest at rest through ix point with maximum inhalation and exhalation, waist, arm at rest, arm at tension, elbow, maximum and minimum forearm, hips, maximum thigh, maximum thigh at 1/2 level, knee, maximum and minimum lower leg. A skinfold caliper was used to take the skin-fold measurement at selected points on the body: biceps and triceps, forearm, iliac crest, lower leg and subscapular skinfold.

The measured values were used to compute the following indices:

- BMI,
- trunk length index,
- upper extremity length index,
- lower extremity length index,
- biextremity index,
- bidactylion diameter index,
- biiliocristal-Biacromial index,
- chest's mobility index.

Two methods, anthropometric and bioelectrical impedance, were used to estimate the amount of body fat.

An equation herein below was used to compute body density (D), which included the skin folds thickness (Lohman 1981):

$$D = 1.0982 - 0.000815(3SF) - 0.000000(3SF)^2,$$

where 3SF stands for a sum of triceps, subscapular and abdomen skinfold. Keys-Brożek equation was applied to compute the percentage of fat (Sinning 1996):

$$\%F = 100 \cdot \left(\frac{4.201}{D} - 3.813 \right),$$

while %FFM = 100% – %F.

The researchers also used the measurement of bioelectrical impendence based on different resistance of certain tissues in human body. The resistance and reactance were measured by the use of bio analyzer instrument BIA 101S by Akern. The device is a four-electrode system which uses hand to foot measurement. The values of passive resistance obtained on the basis of those equations delivered information about the content of total body water (TBW), fat (FM) and fat-free mass (FFM) (Lewitt 2007).

Measurements were conducted by the use of anthropometer (height), large and small spreading calliper (width), Harpenden skinfold calliper (skinfolds) with inter-jaw pressure of $10 g/mm^2$, anthropometric measuring tape (circumferences) and digital scales (body mass).

Analysis was based on basic statistical characteristics. T Student Test for Independent Samples was applied to determine the significance of differences observed between the group of athletes and the control group. The selected features of the athletes were normalized to arithmetic mean, while standard deviation was determined for non-swimming subjects.

The study was approved by the Ethics Committee of the University School of Physical Education in Wrocław.

Results

The swimmers were significantly taller than the non-practicing subjects (Table 1). Their trunk and arms were also longer in comparison to the reference group. Additionally, the swimmers were characterized by a dominant arms range, significantly wider shoulders and chest's depth. Their trochanters' width was significantly smaller than the one observed in non-practicing subjects. Also, the values of shoulder girdle and chest circumferences at maximum inhalation were significantly higher than those obtained by other subjects (Table 2). The circumference of waist, lower leg and subscapular skinfold was significantly higher in non-swimming subjects (Table 3). However, both groups revealed similar values of body mass. Still, BMI index reflecting greater leanness of the athletes was significantly lower in their group. The remaining morphological features examined by the researchers did not reveal any statistically significant differences.

Table 1. Statistical characteristic of length and width features in the examined men

Variable	Swimmers		Control		t-Student test (p)
	x	sd	x	sd	
B-v	182.87	4.92	178.69	6.38	**0.003**
B-sy	95.14	3.74	93.75	4.75	0.178
B-ti	48.40	1.98	48.31	2.65	0.880
da III-da III	188.07	7.26	181.30	7.19	**0.000**
a-a	42.34	1.86	40.67	2.72	**0.003**
dl-dl	47.06	1.90	46.25	3.10	0.192
thl-thl	29.10	1.52	28.91	2.45	0.702
xi-ths	21.44	1.81	19.74	2.08	**0.000**
ic-ic	28.48	1.78	28.11	2.04	0.423
tro-tro	31.12	2.25	32.28	1.72	**0.019**
pte-ap	27.42	1.14	26.88	1.29	0.068
mtt-mtf	10.12	0.64	9.95	0.65	0.281
cl-cm	7.23	0.36	7.04	0.76	0.169
ept-epm	9.98	0.46	9.86	0.65	0.376
a-daIII	80.65	2.78	78.46	3.41	**0.004**
sst-sy	54.13	2.47	51.74	2.86	**0.000**

Table 2. Statistical characteristic of body circumference in the examined men

Variable	Swimmers		Control		t-Student test (p)
	x	sd	x	sd	
Neck circumference (cm)	39.26	2.40	38.52	1.88	0.15
Shoulder girdle circumference (cm)	117.73	5.57	114.55	6.62	**0.03**
Chest circumference in rest (cm)	99.48	5.16	97.41	5.36	0.10
Chest circumference (inspiration) (cm)	105.58	5.26	102.64	5.11	0.02
Chest circumference (expiration) (cm)	93.80	4.84	94.09	5.50	0.81
Chest circumference (xi) in rest (cm)	89.92	4.74	88.72	4.79	0.29
Chest circumference (xi) (inspiration) (cm)	97.11	4.40	94.58	4.63	**0.02**
Chest circumference (xi) (expiration) (cm)	86.70	4.35	85.81	5.37	0.44
Wrist circumference (cm)	78.01	4.41	81.63	5.82	**0.00**
Arm circumference (in rest) (cm)	29.91	2.38	29.70	2.65	0.72
Arm circumference (in tension) (cm)	33.91	2.89	33.32	2.75	0.39
Forearm circumference (max.) (cm)	27.08	1.66	27.71	1.67	0.12
Hip circumference (cm)	97.23	5.16	98.87	4.88	0.17
High circumference (cm)	56.30	4.28	57.39	4.24	0.28
Calf circumference (max.) (cm)	36.89	2.32	38.01	3.39	0.11

Table 3. Statistical characteristic of skinfolds and body mass in the examined men

Variable	Swimmers		Control		t-Student test (p)
	x	sd	x	sd	
Subscapular skinfold (mm)	8.37	2.14	9.63	3.15	**0.05**
Triceps skinfold (mm)	6.08	2.13	6.48	3.52	0.56
Forearm skinfold (mm)	3.68	0.88	3.77	1.32	0.74
Suprailiac skinfold (mm)	8.89	3.65	10.95	6.78	0.11
Stomach skinfold (mm)	9.16	3.72	11.38	6.41	0.07
Calf skinfold (mm)	4.95	1.12	5.80	2.41	0.06
Body mass (kg)	74.76	8.33	75.20	8.51	0.82

The analysis of body proportions enabled them to conclude that relative values of features do not always support the tendencies described hereinabove (Table 4). The index of body length and body height (sst-sy/ height) did not reveal any statistically significant differences. Also, there was no significance in difference between the indices of the upper limb length and body height. Statistically significant difference observed in the swimmers was visible in the values and relative values of shoulders' range and body height. Two methods were used to determine body fatness. There was a distinct difference between the obtained results. The amount of fat computed for the two groups by the use of anthropometric method was significantly lower than the value determined by the BIA method (Table 5). It should be highlighted that the percent of fat determined on the basis of subcutaneous fat tissue revealed significantly lower values in swimmers than in non-swimming subjects. On the other hand, statistically significant differences were not observed in the values computed by the BIA method. The opposite tendencies were observed in reference to the amount of lean body. The amount of water in body evaluated by the use of BIA method was very similar for both groups.

Table 4. Statistical characteristic of anthropometric indices in the examined men

Variable	Swimmers		Control		t-Student test (p)
	x	sd	x	sd	
BMI	22.53	1.85	23.58	2.22	**0.034**
Trunk length index (sst-sy/B-v)	29.60	1.09	28.99	1.94	0.112
Upper extremity length index (a-da3/B-v)	44.11	1.16	43.91	1.08	0.462
Lower extremity length index (B-sy/B-v)	52.02	1.43	52.45	1.55	0.231
Biextremity index (a-da3/B-sy)	84.84	3.19	83.76	2.75	0.134
Bidactylion diameter index (da3-da3/B-v)	102.83	2.56	101.46	1.95	**0.015**
Biiliocristal/Biacromial index (ic-ic/a-a)	67.26	2.89	69.18	3.26	**0.011**
Chest mobility index	11.77	3.78	8.54	2.81	0.000

Table 5. Statistical characteristic of body tissue components in the examined men

Body tissue component	Swimmers		Control		t-Student test (p)
	x	sd	x	sd	
Fat I (%)	8.26	2.25	9.81	4.09	**0.052**
Fat II (%)	20.00	4.27	20.44	4.80	0.688
Lean body I (%)	91.75	2.24	80.19	4.09	**0.051**
Lean body II (%)	80.00	4.27	79.54	4.80	0.688
Body water (%)	58.56	3.13	58.25	3.51	0.695

In order to present the greatest differences between training and non-training subjects, features of the athletes were normalized to arithmetic mean, while standard deviation was determined for non-swimming subjects. Next, the normalized values were used to trace out the morphogram (Figure 1).

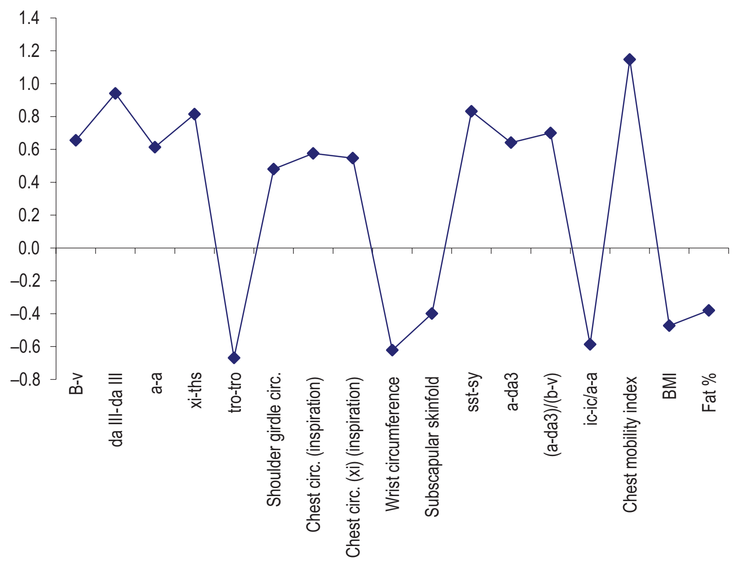

Figure 1. Morphological profile of the swimmers in reference to their non-swimming peers

The chart shows only the features which indicated statistically significant intergroup differences. Among irrelative features in favor of the athletes there were: shoulder range, chest depth and the length of the upper limbs and trunk, while trochanter width and waist circumference were distinctly smaller for the swimmers. The swimmers dominated in the values of mobility of the chest and arm range in reference to body height.

Discussion

Morphological build of swimmers with long training experience results from both the selection process and special training. When systems such as skeletal, joint, muscle and nervous are fully developed, men are in their development phase, where changes shaping their bodies and tissue composition are caused by different exogenic factors e.g. sports training. The results obtained in this research have confirmed many of the previously determined characteristics related to this sports discipline (Carter and Auckland 1994; Pietraszewska 1998; Karpiński and Oprychal 2008). Nevertheless, the differences observed at the development level of the selected somatic features can be ascribed to the different level of skills and the lack of distinction between trained swimming style and distance. Avlonitou (1994) has stated that swimming style leads to the morphological diversification among swimmers. Also Karpiński and Oprychał (2008) have divided the competitors of the Olympic Games in Beijing in reference to their body height, body mass, swimming style and distance. General tendency observed in swimmers is that they are taller than non-swimming subjects. However, it needs to be pointed out that short distance swimmers are taller than long distance competitors. The swimmers examined in this research were also much taller than the control group subjects, however, mean values of height of medalists examined by Karpiński and Oprychał (2008) were slightly lower. Greater body height of swimmers results from the preliminary selection conducted by coaches. The research conducted by Benefice et al. (1990), related to morphological and functional development of young swimmers, confirmed that children who trained swimming were taller than their non-swimming peers. The length of the trunk and upper limbs in the athletes examined in this research were significantly longer than those in non-swimming subjects. Due to the high values of relative length of the trunk and relatively short limbs the gravity center is moved upwards, what makes the legs stay on the surface and the body float on the water more easily. Such features enable to swim faster since they not only improve the angle of attack on water during the performance of swimming movements but also decrease frontal resistance. The situation looks slightly different in the case of swimmer's upper limbs. Swimmers require long upper limbs as they deliver repulsive surface, and due to the suitable swimming technique the losses related to resistance are eliminated. Work performed by the upper limbs with a full range of movement expands their range and strengthens both the shoulder girdle and upper limbs.

Hence, a significant difference observed in the values of the chest depth and its circumference at maximum inhalation supports the idea of body adaptation to the water environment. Additional water resistance put on the chest leads to a development of the respiratory muscles and general improvement of respiratory system, partly by increasing its strength. The lack of significant differences in the lower limbs' bone circumference and massiveness can be explained by the swimming technique. The range of the lower limbs' movement in water is limited so as not to confine the aerodynamic shape of the body. In such manner, even though lower limbs' activity frequently describes a high level of a swimmer, the development of the lower limbs muscles and pelvic girdle is not essential for fast and skillful swimming.

The results obtained from the measurements of subscapular fat tissue indicated lower subscapular fatness in the swimmers in comparison to the non-swimming subjects. It may result from the fact that fat tissue delivers the necessary energy during swimming. However, one should remember that in long-distance swimmers fat tissue is accumulated under the skin in order to provide thermal insulation (Marszałek 2009). That is why, fat deposition observed in different body parts is quite distinct. The amount of fat in swimmers can also be explained by the use of an impedance method which, unlike anthropometric method, takes into account total body fat. The discrepancies observed in the results obtained by the use of those two methods confirm the importance of them both when conducting comparative analysis.

BMI index indicated significantly lower values in swimmers compared to their non-swimming peers. It is conditioned by the selection of subjects with greater body height as well as their long training experience.

The changes observed in a swimmer's body are specifically directed. Like in every endurance effort, also in this case, the fat tissue is burnt and the body becomes leaner. That is why the energy changes used during such effort do not lead to an excessive muscle development, but shape the body in a more balanced way. One should remember that at a distance of 50–100 m the main role is played by anaerobic changes, however, along with a distance those changes become aerobic (Bartkowiak 1999). The athletes examined in this research usually swim longer distances.

The age of the examined athletes, close to the one at which athletes have their greatest achievements (approx. 22 years old), and their long experience, were in accordance with the profiles determined by Karpiński et al. (2005). It means that they were subjected to long and systematic training, which had an influence on the somatic structure of their bodies. Certain features of morphological structure typical to older athletes are already visible in young swimmers. The research conducted by Stanula et al. in 2005 revealed that in groups of 12 year old swimmers the children were already taller and they had longer upper limbs and feet. However, the differences in their body mass were irrelevant. Body tissue composition is characterized by higher fat free mass (FFM) and lower fat mass (FM). The development of metabolically active body components resulting from a systematic training is a factor which conditions a high level of physical capacity in young swimmers (Vaccaro et al. 1980). The research conducted by Avlonitou et al. in 1997, examining correlations between muscle force and body tissue composition in adult swimmers, revealed that high level of physical fitness is conditioned by lean body mass. Thus, it can be stated that differences related to the features necessary to practice this sports discipline develop with age (body height, length of the limbs, length of the trunk), while less important features do not display any significant differences in relation to non-practicing subjects.

The development of children and youth practicing swimming should also be included in the interpretation of some differences. It is quite frequent that people who practice sports are characterized by an increased biological development. According to Malina (1994), first stages of swimming exercises may lead to an increase in the development processes. As stated by the author, the later the subjects grow up, the better sports level they obtain in the future. Regardless of final measurements, swimmers who grow up slower are more flexible and easier to train.

Chest measurements allow for indirect evaluation of breathing abilities of the examined subjects. Chest mobility index is significantly higher in athletes. Its value describes good respiratory ability, which can result from a long training experience.

Conclusions

Athletes performing swimming are characterized by the significant body height, long trunk, wide range of arms and highly developed shoulder girdle. The relation of the trunk to the upper limbs is confirmed by the research conducted on the lead swimmers from Poland and all around the world.

The differences related to length features of the body, observed between the athletes and non-training subjects, can result from many years of training experience. Directed and systematic training has an influence on a great development of the upper part of the trunk and a slight decrease in body fat.

The observed differences indicate that depth, circumference and mobility of the chest developed in swimming have a positive influence on the respiratory system.

Poor differences observed in the amount of fat in the athletes and non-practicing subjects may result from the fact that body accumulates fat tissue, used as a good thermal insulation.

Performing comparison analysis of body tissue composition, it is important to consider two measurement methods, since the applied method determines the difference which may occur in the results.

References

Avlonitou E. Somatometric variables for preadolescent swimmers. J. Sports Med. Phys. Fitness. 1994; 34, 2: 185−191.

Avlonitou E., Georgiou E., Douskas G., Louizi A. Estimation of body composition in competitive swimmers by means of three different techniques. Int. J. Sports Med. 1997; 18 (5): 363–368

Bartkowiak E. Pływanie. Program szkolenia dzieci i młodzieży. Centralny Ośrodek Sportu. Warszawa 1999

Benefice E., Mercier J., Guerin M.J., Prefaut C. Differences in aerobic and anthropometric characteristics between peripubertal swimmers and non-swimmers. Int. J. Sports Med. 1990; 11, 6: 456−460.

Carter J.E.L., Ackland T.R. Kinanthropometry in Aquatic Sports: A study of world class athletes. Champaign: Human Kinetics. 1994.

Czabański B., Fiłon M. Elementy teorii pływania. Wydawnictwa Akademii Wychowania Fizycznego we Wrocławiu. Wrocław 1994.

Drozdowski Z. Antropologia sportowa. AWF. PWN. Poznań 1984.

Karpiński R., Opyrchał C. Pływanie na Igrzyskach Olimpijskich w Pekinie – analiza poziomu sportowego, wieku i budowy somatycznej pływaków. Sport Wyczynowy. 2008; 10–12: 7–23.

Karpiński R., Sachnowski K., Oprychał C. Zmiany w szkoleniu pływaków najwyższej klasy. Sport Wyczynowy. 2005; 5–6: 57–67.

Lewitt A., Mądro E., Krupienicz A. Podstawy teoretyczne i zastosowania analizy impedancji bioelektrycznej (BIA). 2007.

Lohman T.G. Skinfolds and body density and their relation to body fatness: A Review. Hum Biol. 1981; 53: 181–225.

Malina R.M. Physical growth and biological maturation of young athletes. Exercise and Sports Sciences Reviews. Exerc. Sport Sci. Rev. 1994; 22: 389−433.

Marszałek A. Czynniki kształtujące tolerancje zimnego środowiska. Centralny Instytut Ochrony Pracy – Państwowy Instytut Badawczy. 2009.

Pietraszewska J. Zróżnicowanie morfologiczne zawodników różnych dyscyplin sportowych. AWF. Wrocław 1998.

Sachnowski K., Oprychał C., Karpiński R. Wybrane problemy selekcji w procesie wieloletniego szkolenia. Sport Wyczynowy. 2005; 11–12: 224–227.

Sinning W.E. Body composition in Athletes. In: Human Body composition, eds. A. Roche, S.B. Heymsfield, T.G. Lohman. Human Kinetics. 1996.

Stanula A., Cholewa J., Zając A. Body composition and chosen anthropometric variables in young swimmers. Annales Universitatis Mariae Curie-Skłodowska. Lublin 2005; Vol. LX, suppl. XVI: 224–228.

Vaccaro P., Clarke D.H., Morris A.F. Physiological characteristics of young well-trained swimmers. Eur. J. Appl. Physiol. Occup. Physiol. 1980; 44, 1: 61−66.

Wieczorek W. Ocena prawidłowości doboru dzieci do sportu pływackiego. Uniwersytet Łódzki. Łódź 2001: 31–54.

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