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Associations between morphological dimensions and swimming time in different swimming styles

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Abstract

The morphology of young athletes is an important selection factor when choosing sports and sports disciplines. In swimming, morphology has an influence on the choice of swimming style and is somewhat related to the improvement of results. In this research, 27 anthropometric dimensions were measured on a sample of 132 young swimmers. The swimmers were members of several Belgrade swimming clubs (aged 10-18), and were divided into three age-subsamples. The aim of this research is to determine the relationship between different age-groups morphology and the swimming time at 50m for different swimming styles. Descriptive indicators showed deviations from the measures of the general population, which describes the training adaptations of young swimmers' bodies. The results of correlation analysis show significant positive and negative correlations ($p<0.01$) of morphological dimensions and swimming results in all age groups and swimming styles. Strong positive correlations were obtained between swimming time in breaststroke style: with foot wide ($r=0.97$) in second and third age groups, as well as in butterfly style with thickness of skin fold of biceps ($r=0.80$), chest ($r=0.95$), stomach ($r=0.92$), upper leg ($r=0.88$) and back ($r=0.83$) in second age group. A strong significant negative correlation was observed between swimming time in butterfly style and shoulders width ($r=-0.85$) in third age group. This research can help professors of physical education and sports coaches to facilitate the process of selection and categorization of their students or athletes.

Keywords: *Swimmers, morphology, anthropometrics, swimming styles, swimming time*

Introduction

Achievements in sports show a constant improvement in results in all age categories of athletes and at all levels of competition. In Swimming as an Olympic sport, there is also a constant improvement in results from year to year (Markovic, 2017). Unlike group games where physical predispositions can be compensated by technical and tactical elements, in basic individual sports such as swimming, the variance of hereditary factors can hardly be compensated through training (Markovic & Milosevic, 2023). Body morphology is one of the main hereditary factors behind top results in swimming (Kumar & Solanki, 2019). In selection and early training process, by applying a system of anthropometric measurements, we obtain more precise data on the optimal physical development of the athlete (Leko et al., 2004). The ratio of muscle mass, limb length and joint mobility divides swimmers according to swimming styles (Damsgaard et al., 2001). Functional, motor and psychological components affect the duration of work (Rozi et al., 2019). That is why the selection should be based, on stable parameters, e.g., morphological parameters, and athletes should be selected based on them (Popo et al., 2010). In order to make this possible, it is necessary to systematically record and describe the morphological dimensions of young swimmers of different ages and swimming styles. Although there are numerous studies on this topic (Lima et al., 2022), a comprehensive and systematic measurement has so far been lacking.

Morphological analyses indirectly indicate that swimmers'anthropometric dimensions are related to their performance, results and the swimming style they compete in (Sekulic et al., 2007). In general, sprint free stylers are taller, with longer arms, heavier and more muscular than middle and long distance free stylers and other stroke specialists (Carte et al., 1994). It seems that greater body height is a performance-de-

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termining factor for sprint, but that it is not so critical for long distance races (Kjendlie & Stallman, 2011). Body mass and BMI are lower in long-distance swimmers due to significant fat burning during swimming aerobic training (Vasileva et al., 2022). Body mass index is a poor predictor of performance and appears as a low-informative morphological feature in swimming (Pla et al., 2022).The results showed that older swimmers had higher body mass values compared to younger swimmers, and significant differences in upper limb strength indicators (Marinho et al., 2021).

When it comes to direct correlation observation, the results are inconsistent. Somatotype and body structure do not show a high correlation in swimming 100 meters at a younger age (Leko, et al., 2011). Junior group revealed a significant relationship between somatic traits (BM, BH, AS and BMI) and swimming speed for 50m crawl style (Strzala et al., 2019). However, the association of certain morphological dimensions in swimmers of different styles and ages, with young athletes, has not been observed in detail in previous studies.

The aim of this study is to examine anthropometric dimensions in three age categories of swimmers and their correlation with the results of swimming at 50 m in different swimming styles. We hypothesise that at different ages and with different styles, various morphological dimensions will correlate to the swimming result. Present findings should contribute to the efficiency of both, the selection process and the improved monitoring of the training process effects of the young swimmers.

Methods

Participants

The sample included in this research consists of N=132 male swimmers, aged 10 to 18, who are active competitors in four Belgrade swimming clubs. The entire sample was divided into three subsamples according to age: 10-12 years (n1=55), 13-16 years (n2=47) and 17-18 years (n3=30). Before the study, parents or guardians of the participants singed voluntary consent to participate. The study was carried out with the consent of the Ethics Commission of the Singidunum University (No. 123).

Morphological characteristics assessment

For the assessment of morphological characteristics, 27 anthropometric variables were applied according to the procedure established by the International Biological Program (IBP) (Stojanovic et al. 1975):

1. Longitudinal dimensionality of the body (body height-BH, arm length-AL, hand length-HL, leg length-LL and foot length-FL);
2. Transversal dimensionality of the body (shoulders width-SW, hand width-HW, pelvis width-PW, foot wide- FW, elbow diameter-ED, hand diameter-HD, knee diameter-ND, foot diameter-FD);
3. Body mass and volume (body mass-BM, chest circumference-CC, upper arm circumference-UAC.forearm circumference-FAC, upper leg circumference-ULC and lower leg circumference-LLC) and
4. Subcutaneous adipose tissue (thickness skin fold biceps-TSFBc, thickness skin fold triceps-TSFTc, thickness skin fold fore arm-TSFFA, thickness skin fold chest-TSFC, thickness skin fold back-TSFB, thickness skin fold stomach-TSFS, thickness skin fold upper leg-TSFUL and thickness skin fold lower leg-TSFLL).

Swimming time assessment

Swimming time for 50 m in all swimming styles was measured in groups of 6 in the semi-Olympic pool „Mirko Sandic"in the Belgrade municipality of Vracar.

Statistical analyses

The data obtained were processed in SPSS 22 using descriptive statistics and correlation analysis. Arithmetic mean and standard deviation were calculated for all age-groups. A bivariate Pearson's correlation analysis was applied to describe the relationships between anthropometric variables and swimming time in different groups.

Results

The results of descriptive statistical parameters of anthropometry by styles and ages are presented in Table 1.

The results of the correlation analysis between the anthropometric variables and the results at 50m by styles through different age periods are presented in Table 2.

Table 1. Descriptive analysis of the first (N=55), the second (N=47) and the third (N=30) subsample of swimmers.

	FREE			BACK			BREAST			FLY		
	M ± SD			M ± SD			M ± SD			M ± SD		
AGE	1	2	3	1	2	3	1	2	3	1	2	3
BM	45.29 ± 9.1	67.37 ± 5.52	69.48 ± 5.85	44.57 ± 9.91	65.37 ± 9.59	70.00 ± 9.65	41.81 ± 9.99	62.02 ± 10.26	74.88 ± 6.68	40.52 ± 12.87	72.86 ± 13.71	69.57 ± 6.05
BH	154.66 ± 9.16	179.1 ± 6.47	180.49 ± 3.69	152.6 ± 10.15	175.1 ± 10.82	184.9 ± 5.48	151.01 ± 7.91	172.84 ± 10.52	183.6 ± 7.46	146.8 ± 13.25	176.5 ± 6.77	176.9 ± 7.27
AL	66 ± 4.44	78.61 ± 3.92	78.09 ± 2.54	65.07 ± 5.77	75.61 ± 4.82	77.20 ± 4.37	64.84 ± 3.48	74.19 ± 5.43	79.92 ± 3.20	62.87 ± 6.24	75.54 ± 3.23	76.17 ± 3.34
HL	16.04 ± 1.12	18.80 ± 1.35	18.67 ± 0.52	15.84 ± 1.25	17.80 ± 1.39	19.10 ± 1.00	15.35 ± 0.98	18.54 ± 1.15	18.90 ±0.45	14.99 ± 1.5	18.44 ± 0.94	18.51 ± 0.54
LL	88.23 ± 5.36	102.7 ± 4.58	101.6 ± 2.85	87.83 ± 7.35	101.7 ± 5.38	102.76 ± 3.26	87.22 ± 5.15	99.09 ± 6.19	105.0 ± 5.49	84.25 ± 8.08	101.1 ± 4.50	100.1 ± 4.11
FL	25.22 ± 1.51	28.72 ± 1.72	27.95 ± 1.00	24.64 ± 1.65	27.72 ± 1.09	28.10 ± 0.65	24.38 ± 1.39	27.68 ± 1.31	29.00 ± .53	23.82 ± 2.21	27.80 ± 1.18	27.52 ± 0.84
SW	33.98 ± 2.31	40.15 ± 1.71	41.75 ± 1.72	33.54 ± 2.59	39.15 ± 2.87	43.10 ± 2.17	32.78 ± 1.72	38.26 ± 2.56	41.76 ± 2.95	33.34 ± 3.15	41.31 ± 1.81	41.52 ± 2.14
HW	7.16 ± 0.51	8.11 ± 0.38	8.13 ± 0.33	7.02 ± 0.4	7.71 ± 0.42	7.70 ± 0.26	6.79 ± 0.51	8.16 ± 0.45	8.20 ± 0.25	6.8 ± 0.6	8.14 ± 0.36	8.00 ± 0.38

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Table 1. Descriptive analysis of the first (N=55), the second (N=47) and the third (N=30) subsample of swimmers.

	FREE			BACK			BREAST			FLY		
	M ± SD			M ± SD			M ± SD			M ± SD		
AGE	1	2	3	1	2	3	1	2	3	1	2	3
PW	23.91 ± 2	27.71 ± 0.61	28.54 ± 0.98	23.63 ± 1.65	27.31 ± 2.33	29.10 ± 1.51	23.22 ± 1.82	27.05 ± 1.97	28.34 ± .56	22.86 ± 2.74	28.68 ± 1.62	27.83 ± 1.49
FW	8.29 ± 0.51	9.71 ± 0.58	9.34 ± 0.70	8.19 ± 0.68	9.51 ± 0.66	9.60 ± 0.40	7.92 ± 0.65	9.26 ± 0.50	9.42 ± 0.23	7.76 ± 0.74	9.74 ± 0.53	9.38 ± 0.47
ED	6.2 ± 0.41	7.18 ± 0.32	6.99 ± 0.19	6.23 ± 0.36	7.11 ± 0.44	7.23 ± 0.45	5.88 ± 0.48	7.01 ± 0.45	7.00 ± 0.12	6.08 ± 0.46	7.10 ± 0.42	7.03 ± 0.23
HD	5.16 ± 0.34	5.82 ± 0.33	5.69 ± 0.22	5.05 ± 0.28	5.62 ± 0.42	5.76 ± 0.28	4.95 ± 0.31	5.85 ± 0.32	5.60 ± 0.29	4.94 ± 0.47	5.74 ± 0.34	5.78 ± 0.28
ND	9.2 ± 0.43	9.90 ± 0.37	9.75 ± 0.43	8.93 ± 0.41	9.80 ± 0.36	9.96 ± 0.46	8.98 ± 0.72	9.80 ± 0.38	9.80 ± 0.45	8.83 ± 0.64	9.94 ± 0.50	9.61 ± 0.46
FD	7.1 ± 0.25	7.81 ± 0.30	7.63 ± 0.16	7.05 ± 0.26	7.71 ± 0.38	7.93 ± 0.41	7.03 ± 0.47	7.60 ± 0.32	7.56 ± 8.94	6.81 ± 0.5	7.67 ± 0.49	7.47 ± 0.36
CC	77.37 ± 6.72	93.11 ± 3.18	95.42 ± 4.38	76.78 ± 6.73	91.11 ± 7.36	94.56 ± 3.85	73.23 ± 5.47	88.52 ± 6.88	96.12 ± 4.95	75.13 ± 8.71	94.62 ± 8.20	95.07 ± 3.56
UAC	23.36 ± 2.8	27.84 ± 1.52	28.66 ± 1.98	23.94 ± 2.95	27.14 ± 1.93	27.20 ± 2.57	21.84 ± 3.26	26.48 ± 2.24	29.10 ± 1.67	22.28 ± 3.31	28.87 ± 3.60	28.93 ± 1.83
FAC	21.78 ± 1.59	25.50 ± 1.25	25.51 ± 0.99	21.72 ± 1.85	25.00 ± 1.34	25.30 ± 1.53	20.84 ± 2.04	24.74 ± 1.83	25.76 ± 0.85	20.8 ± 2.28	25.95 ± 1.83	25.70 ± 1.09
ULC	47.61 ± 4.73	53.41 ± 2.57	54.04 ± 3.22	47.38 ± 5.6	53.11 ± 3.64	51.76 ± 3.51	45.76 ± 6.26	52.27 ± 4.08	57.10 ± 3.78	45.32 ± 5.58	56.85 ± 5.89	54.15 ± 3.71
LLC	31.9 ± 2.62	35.72 ± 1.38	35.87 ± 1.89	31.31 ± 2.92	35.52 ± 2.02	35.83 ± 2.66	30.52 ± 3.7	34.90 ± 2.23	37.44 ± 1.46	29.77 ± 3.47	37.60 ± 3.50	36.36 ± 2.11
TSFBc	5.81 ± 2.15	4.05 ± 1.01	4.06 ± 1.18	6.33 ± 2.33	4.00 ± .70	3.56 ± 0.11	6.1 ± 3.95	4.45 ± 1.39	4.64 ± 1.05	5.5 ± 0.94	5.22 ± 2.02	4.41 ± 1.65
TSFTc	12.13 ± 4.15	8.31 ± 2.59	8.72 ± 3.40	18.04 ± 20.49	8.11 ± 2.28	6.36 ± 0.35	11.76 ± 6.78	8.96 ± 2.38	10.52 ± 3.90	12.02 ± 3.54	11.83 ± 5.61	8.91 ± 5.27
TSFFA	6.33 ± 1.87	4.17 ± .88	4.11 ± 1.09	6.31 ± 2.07	4.07 ± .89	4.13 ± 0.70	6.03 ± 2.67	4.79 ± 1.20	4.70 ± 1.01	5.87 ± 1.72	5.49 ± 2.05	4.61 ± 1.30
TSFS	15.28 ± 12.3	10.05 ± 2.80	10.99 ± 5.92	15.13 ± 12.54	9.85 ± 2.57	5.93 ± 1.00	11.84 ± 12.71	11.98 ± 6.68	16.56 ± 7.75	12.19 ± 11.84	20.81 ± 20.70	12.66 ± 11.19
TSFC	8.21 ± 5.29	4.72 ± .73	5.25 ± 1.37	8.02 ± 4.98	4.52 ± .49	4.60 ± 0.36	7.26 ± 7.06	5.42 ± 1.53	6.54 ± 1.89	7.17 ± 4.34	8.56 ± 6.93	5.65 ± 2.39
TSFB	6.99 ± 2.45	6.88 ± 1.70	7.67 ± 1.51	7.23 ± 2.31	6.68 ± 1.69	5.60 ± 1.30	7.01 ± 5.54	7.16 ± 1.29	9.44 ± 2.72	6.08 ± 1.54	9.33 ± 5.69	8.11 ± 1.81
TSFUL	18.2 ± 7.81	9.94 ± 1.85	12.23 ± 4.21	18.64 ± 6.87	9.74 ± 3.02	8.26 ± 0.64	16.87 ± 8.99	12.02 ± 4.04	15.22 ± 3.25	16.29 ± 6.26	16.50 ± 6.35	12.51 ± 7.96
TSFLL	12.78 ± 4.23	7.35 ± 1.14	9.15 ± 3.71	14.08 ± 5.1	7.25 ± 2.75	7.33 ± 0.98	12.52 ± 7	10.13 ± 3.38	10.66 ± 3.28	11.55 ± 3.68	11.26 ± 3.99	9.23 ± 6.17

Table 2. Correlations of parameters in the first, second and third subsample of swimmers

AGE	50m FREE			50 m BACK			50 m BREAST			50 m FLY		
	1	2	3	1	2	3	1	2	3	1	2	3
BM	-0.358 0.132	-0.313 0.495	-0.709 **0.010**	-0.446 0.095	-0.222 0.566	-0.363 0.173	-0.108 0.661	-0.348 0.204	0.163 0.794	-0.549 0.100	0.760 **0.011**	-0.359 0.383
BH	-0.393 0.096	0.223 0.631	-0.063 0.845	-0.614 **0.015**	-0.025 0.949	-0.669 0.534	-0.286 0.236	-0.488 0.065	0.383 0.525	-0.522 0.122	0.192 0.595	-0.494 0.214
LL	-0.442 0.058	0.269 0.559	-0.152 0.638	-0.647 **0.009**	0.175 0.652	-0.801 0.409	-0.274 0.256	-0.464 0.082	0.704 0.185	-0.483 0.157	0.021 0.954	-0.032 0.940
SW	-0.305 0.204	-0.156 0.738	-0.468 0.125	-0.537 **0.039**	-0.187 0.631	-0.991 0.086	-0.211 0.386	-0.520 **0.047**	-0.564 0.322	-0.521 0.122	0.337 0.341	-0.852 **0.007**

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Table 2. Correlations of parameters in the first, second and third subsample of swimmers

AGE	50m FREE			50 m BACK			50 m BREAST			50 m FLY		
	1	2	3	1	2	3	1	2	3	1	2	3
PW	-0.444	-0.172	-0.600*	-0.588	-0.218	-0.926	0.064	-0.543*	0.023	-0.571	0.230	-0.774
	0.057	0.712	**0.039**	**0.021**	0.574	0.247	0.796	**0.036**	0.971	0.085	0.523	**0.024**
ED	-0.367	-0.369	0.085	-0.377	-0.278	-0.043	-0.108	-0.434	-0.273	-0.574	0.225	-0.095
	0.122	0.416	0.792	0.166	0.469	0.972	0.660	0.106	0.656	0.082	0.531	0.823
HD	-0.270	-0.328	0.071	-0.555	-0.446	-0.518	-0.374	-0.396	-0.394	-0.484	0.103	-0.097
	0.264	0.472	0.826	**0.032**	0.228	0.653	0.115	0.143	0.512	0.156	0.777	0.820
HL	-0.201	-0.515	-0.375	-0.540	-0.391	0.876	-0.134	-0.634	0.121	-0.424	-0.097	-0.429
	0.409	0.237	0.229	**0.038**	0.298	0.320	0.584	**0.011**	0.846	0.222	0.791	0.289
HW	-0.304	-0.817	-0.011	-0.502	-0.024	-0.670	-0.174	-0.522	0.269	-0.505	0.516	-0.031
	0.206	**0.025**	0.974	0.057	0.950	0.532	0.477	**0.046**	0.662	0.137	0.127	0.942
CC	-0.433	-0.160	-0.621	-0.570	-0.395	-0.944	-0.112	-0.666	-0.179	-0.623	0.758	-0.438
	0.064	0.732	**0.031**	**0.026**	0.293	0.215	0.648	**0.007**	0.773	0.054	**0.011**	0.278
UAC	-0.214	-0.625	-0.622	-0.301	-0.221	-0.972	-0.142	-0.436	-0.486	-0.570	0.702	0.040
	0.380	0.133	**0.031**	0.276	0.568	0.151	0.562	0.105	0.407	0.085	**0.024**	0.926
FAC	-0.327	-0.566	-0.540	-0.370	-0.303	-0.950	-0.194	-0.381	-0.417	-0.556	0.539	-0.271
	0.172	0.185	0.070	0.174	0.429	0.202	0.427	0.161	0.485	0.095	0.108	0.516
ULC	-0.136	-0.757	-0.566	-0.271	-0.305	-0.972	-0.188	-0.088	0.341	-0.590	0.669	0.158
	0.578	0.049	0.055	0.329	0.424	0.150	0.440	0.755	0.574	0.073	**0.034**	0.709
LLC	-0.134	0.058	-0.656	-0.323	-0.268	-0.982	-0.180	0.027	-0.641	-0.625	0.717	-0.399
	0.585	0.902	**0.021**	0.240	0.486	0.121	0.460	0.924	0.244	0.053	**0.020**	0.327
TSFBc	-0.039	-0.555	-0.020	-0.256	0.224	-0.482	0.104	0.409	0.631	-0.515	0.804	0.642
	0.874	0.196	0.952	0.357	0.562	0.680	0.671	0.130	0.254	0.128	**0.005**	0.086
TSFFA	0.124	-0.472	-0.316	-0.054	-0.558	0.428	0.186	0.502	0.229	-0.165	0.798	0.654
	0.614	0.285	0.317	0.849	0.119	0.243	0.446	0.056	0.712	0.648	**0.006**	0.078
TSFC	0.194	-0.473	0.040	-0.105	-0.213	-0.220	0.152	0.508	0.918	-0.586	0.954	0.534
	0.427	0.283	0.901	0.711	0.581	0.859	0.536	0.053	**0.028**	0.075	**<0.001**	0.173
TSFS	0.170	-0.613	-0.064	-0.060	-0.153	-0.094	0.012	0.377	0.825	-0.354	0.928	0.522
	0.486	0.143	0.844	0.831	0.695	0.940	0.960	0.166	0.086	0.315	**<0.001**	0.184
TSFUL	0.236	-0.501	0.475	-0.019	0.231	-0.340	-0.010	0.619	0.170	-0.551	0.880	0.520
	0.332	0.252	0.624	0.947	0.549	0.779	0.968	**0.014**	0.785	0.099	**0.001**	0.186
TSFLL	0.152	-0.314	-0.029	0.065	0.146	0.482	0.046	0.693	0.492	-0.556	0.492	0.585
	0.533	0.493	0.928	0.819	0.707	0.680	0.850	**0.004**	0.400	0.095	0.148	0.128
TSFTc	0.088	0.358	-0.172	-0.254	0.384	0.810	0.037	0.432	0.279	-0.360	0.663	0.605
	0.719	0.430	0.594	0.361	0.308	0.399	0.879	0.108	0.650	0.308	**0.037**	0.112
TSFB	0.239	0.376	-0.131	-0.194	-0.552	-0.021	0.338	-0.068	0.546	-0.461	0.833	0.231
	0.324	0.406	0.686	0.488	0.123	0.987	0.158	0.809	0.341	0.179	**0.003**	0.581
ND	-0.165	-0.021	0.044	-0.484	-0.103	-0.482	-0.273	-0.110	0.724	-0.521	0.518	-0.005
	0.499	0.964	0.892	0.067	0.791	0.680	0.259	0.695	0.166	0.122	0.125	0.990
FD	-0.044	-0.053	0.324	-0.335	-0.355	-0.678	-0.441	-0.475	0.082	-0.472	0.484	-0.274
	0.857	0.910	0.304	0.223	0.348	0.526	0.059	0.073	0.896	0.169	0.156	0.511
FW	-0.248	-0.045	-0.343	-0.255	-0.407	-0.855	-0.162	-0.372	0.972	-0.489	0.357	0.187
	0.305	0.924	0.275	0.359	0.277	0.347	0.507	0.172	**0.006**	0.151	0.311	0.658
FL	-0.336	0.054	-0.132	-0.706	-0.001	-0.780	-0.025	-0.422	0.224	-0.607	0.217	0.207
	0.159	0.908	0.683	**0.003**	0.997	0.431	0.918	0.117	0.717	0.063	0.547	0.622
AL	-0.355	0.184	-0.190	-0.608	0.075	0.078	-0.295	-0.440	0.551	-0.470	0.128	-0.548
	0.136	0.694	0.555	**0.016**	0.849	0.950	0.220	0.100	0.336	0.171	0.724	0.160

Note: Significant values are marked in bold.

Discussion

This study aimed to describe and analyse the relationship of morphological dimensions with the swimming time of young swimmers in different swimming styles. Detailed description of morphological dimensions considering the three age groups as well as the four main swimming styles was provided. Also, numerous correlations of morphological dimensions and swimming time were obtained in all age groups and swimming styles.

In the first age group, freestyle swimmers showed a significant correlation with the 50m result in the variables: BH, LL, PV and CC, which shows that total body height and especially

long legs follow fast crawl swimming. Similarly to these findings, body height, arm length and hand length showed earlier to be related to the result in 50m crawl and back stroke styles (Dimitric, et al., 2010).

In the case of back technique, the most significant correlations with the result are with the longitudinal and transfer dimensions (BM, BH, LL, SV, HD, HV, CC, PV, FL and AL).These results are also in line with the earlier findings that suggest that developed arm musculature improved the efficiency of backstroke swimmers (Sammound et al., 2018).

Breaststroke swimmers showed the weakest correlation of anthropometric variables and swimming time with the youngest age group, probably due to the marked difference in the development of swimmers. The only significant correlation with the 50 m result is with FD, which indicates the importance of foot shape in leg propulsion. The flexibility of ankle joint is important in the leg work of breaststrokers (Jagomagi & Jurimate, 2005). Butterfly technique swimmers have a correlation of results with anthropometric variables with PW, CC, UAC, FAC, ULC and LLC. These correlations may suggest that effective swimming for butterfly swimmers entails strong chest, arms and legs (Leko et al.,2004), due to strong arm propulsion and leg kicking (Grcic-Zupcevicet al., 2004).

In the second age period that included freestyle swimmers, the correlation of results is only with HW and ULC. This shows that larger hand dimensions and stronger quadriceps contribute to better efficiency in arm propulsion (S-stroke), and the efficiency of leg work. No correlation between variables was observed with backstroke swimmers at this age, so the result must be influenced by additional factors such as the training process.

With breaststroke swimmers in second age group, ten variables have a good correlation with the result at 50 m. The variables BH LL, SW PW, HL, HW, FD, CC, TSFUL and TSFLL record good correlations with the result. This finding is in accordance with previous studies which showed that overall body height and particularly length of the legs as well as wide shoulders are characteristics of good breaststroke swimmers (Nevill et al., 2018), (Trivun et al., 2011). This shows that the longitudinal and transversal dimensions of the feet and hands have role in improving the propulsion of arms and legs, leading to better results. When it comes to butterfly, body mass, circumferences and TSF show a significant relationship with the result. This indicates that the chest muscles, the back and arms have significant role in the propulsion of the arms, and the leg muscles are important for a more efficient kick. This is in line with previous study in which the swimming time in 100 m butterfly was correlated with muscles mass (Bouguezzi et al., 2018).

With the third age, the connection between variables was the weakest, partly due to the small sample. Freestyle swimmers showed a good correlation of swimming time with BM, PW, CC, UAC, FAC, ULC and LLC. This indicates that large and massive swimmers are needed for a better result of a 50m crawl swimmer. Volumes of body change drastically under the influence of training at a younger age, but later they stabilize (Gualdi&Graziani, 1993).

With backstroke swimmers the only significant correlation of the results is with SW, which helps the body move better in the water. The results of these swimmers correlated with TSFC and TSFTc (stronger arm stroke) and with FW (more efficient leg push). Butterfly swimmers also have a smaller number of significant connections than the other age groups, which means that the development of butterfly swimmers has stabilized. The results correlate only with four variables: CW and PW contributes to a better body position and TSFBc and TSFFA contribute to a stronger arms stroke (Sammoud et al., 2018).

Conclusion

The findings of this study provide a detailed description of the morphological dimensions of the three age groups of swimmers who employed four swimming styles. Obtained correlation with swimming time in first age group are highest for the backstroke technique with longitudinal and transverse dimensionality indicators. In the second age group, the swimmers of butterfly styles showed significant correlation of swimming time with body volume and mass. The breaststroke swimmers showed significant correlations of swimming time with transfer, girth and TSF of the legs. In the third group, the body mass and volumes of freestyle swimmers were correlated with swimming time.

The results obtained in this research provide insight into possible influences of morphological characteristics on swimming time with different swimming styles. A more detailed conclusion to this topic requires further experimental studies. Nevertheless, the results of this research provide a guideline for the swimming clubs and all swimming workers of the Swimming Federation of Serbia to carry out an adequate selection of young swimmers and to categorize them in different swimming styles based on their morphological characteristics.

Conflict of interest

The authors declare that there is no conflict of interest.

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