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Relationship Between Body Composition and Sprint Swimming Performances in Butterfly Sprinter: Seven-Year Longitudinal Single-Case Study

Relación Entre la Composición Corporal y el Rendimiento en Natación de Velocidad en Velocistas Mariposa: Estudio Longitudinal de Caso Único de Siete Años

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DOPSAJ, M. & SILJEG, K. Relationship between body composition and sprint swimming performances in butterfly sprinter: Seven-year longitudinal single-case study. *Int. J. Morphol., 43(4)*:1260-1266, 2025.

SUMMARY. The study aims to determine the relationship between variables that define body composition characteristics and sprint swimming performance in elite male butterfly sprinters. The study was conducted over a seven-year longitudinal period with subjects aged 18 to 24 years. During the mentioned period, the subject was measured 10 times, with body composition measurements by multichannel segmental bioimpedance method with the InBody720 device realized a week before the most important competition, regardless of the length of the pool (25 or 50 m pool) or swimming distance (50 or 100 m). The results of the correlation analysis showed that only skeletal muscle mass index (SMMI) was statistically significantly correlated with swimming performance (r = -0.917 to -0.971), and that correlation was slightly higher on the 50 m compared to the 100 m distance, as well as the results achieved in the 25 m compared to the 50 m pool. No statistically significant correlation was found for the other body composition variables used in this research (fat mass index - FMI, protein-fat index - PFI, percent of skeletal muscle mass - PSMM, index of body composition - IBC and percent of body fat - PBF). This research has shown that it is necessary to establish a research principle, that the impact of body composition changes and relationships on sports performance should be realized as an individual methodological procedure in elite sports.

KEY WORDS: Body composition; Swimming performance; Butterfly stroke; Individual approach.

INTRODUCTION

The phenomenon of adaptation represents the process of biological reintegration and habituation of living organisms to environmental conditions, i.e. environment. Each organism of an athlete is in a reciprocal dynamic relationship with its environment with a tendency to adapt its functional, physiological, psychological, cognitive, physical abilities and morphological characteristics to the systematic, long-term multi-year training and competition loads to which it is exposed (Ushakov *et al*., 2024). Adaptation is always specific and has structured processes in different individuals, in terms of the level of biological potential, intensity and functional structure, despite the same stimulus from external factors (Milisic, 2007). In other words, to the same training stimulus - to the same single training session, different subjects will not adapt in exactly the same way. That is why the analytical approach to evaluating the effects of training has two directions – general, for sample, group and/or team and individual, as an analytically single approach (Bartlett *et al*., 2017).

The individual principle to control the effects of training in order to define the precise individual effect on the athlete, although it may have a multidisciplinary approach, is mainly carried out through the monitoring of single and/or a smaller number of systemically important variables (Mujika *et al*., 2018; Siljeg *et al*., 2023).

In previous research, where the phenomenology of the relationship between body composition and swimming performance was examined in international sprint swimmers, a statistically significant correlation was established for different variables of body composition in both females and males (Siders *et al*., 1993). It was established that the relationship between body composition and swimming

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performance is more complex and statistically more significant in female than in male swimmers (Dopsaj *et al*., 2020). But, all these relations were defined in transversal ie. cross-selection studies, and on larger samples of competitive swimmers, which means that the results represent generalized data on the relationship between anthropometry and body composition and swimming performance. Generalized conclusions represent the basis of general knowledge and are the basis for work in sports training practice, but during individual work they do not have to represent a specific and realistic meaning in the control of improving competitive performance in relation to an individual swimmer.

The aim of the study is to determine the relationship between variables defining body composition and sprint swimming performance in elite butterfly sprinters over a seven-year longitudinal period. In this way, relations between the characteristics of body composition, the characteristics of changes in body composition in relation to the functional specificity of tissues, in relation to the individual level of adaptation of the examined swimmer, will be determined. Also, the paper should provide methodological specifics for the principle of individualization when working with top athletes.

MATERIAL AND METHOD

This research was carried out as a 7-year longitudinal single-case follow-up study in the period from 2018 to 2024, using the laboratory testing method. Research was carried out with the subject's personal consent, and all measurements were carried out at the Faculty of Sports and Physical Education of the University of Belgrade in the Methodological Research Laboratory by the same personnel on the same equipment. During the monitoring period, the equipment was regularly maintained and calibrated by the official technical service (https://borf.rs/inbody-proizvodi/). The research was carried out (Christie, 2000) in accordance with recommended standards of the "Declaration of Helsinki for Recommendations that guide doctors in biomedical research involving human subjects" - (http://vvv.cirp.org/librari/ethics/helsinki/), and with the approval of Ethics Committee of the Faculty of Sports and Physical Education, University of Belgrade (484-2).

Subject sample. In the period from 2018 to 2024, one swimmer (Dj.M, male, follow-up period from 18 to 24 years) was monitored. In the given period, the subject was measured 10 times, with body composition measurements performed a week before the most important competition, regardless of the length of the pool (25 or 50 m pool).

Body Composition Measurement. All body composition measurements were carried out using a standardized procedure and using the multichannel segmental bioimpedance method with the InBody720 device (Zaric *et al*., 2020; Dopsaj *et al*., 2024). All measurements were carried out in the morning hours (between 08:00 and 09:00), where the subject did not take water and food that morning before the measurement, and at least 48 hours before had no high-load training. During the measurement, the subject was in a swimming suit.

Variables

Body Composition. In this research, variables representing body composition from the aspect of contractile and ballast components were used. The given variables are partialized in relation to the voluminosity and longitudinality of the body (Dopsaj *et al*., 2024). Also, two index variables were used, which were previously shown to be very informative indicators of body composition (Kukic *et al*., 2020; Dopsaj *et al*., 2020; Toskic *et al*., 2024; Richa *et al*., 2024). The following variables used in this research were:

1. FMI, fat mass (FM) index, as a measure of total body fat mass independent of body longitudinality, calculated as: FM/BH^2 (m), expressed in $kg \cdot m^{-2}$;
2. SMMI, skeletal muscle mass (SMM) index, as a measure of the total muscle mass of the body independent of body longitudinality, calculated as: SMM/BH^2 (m), expressed in $kg \cdot m^{-2}$;
3. PBF, body fat (BF) percent, as a measure of body fat mass independent of body mass (BM), as an basic measure of body voluminosity, calculated as: BF/BM, expressed in %;
4. PSMM, skeletal muscle mass percent, as a measure of skeletal muscle mass independent of body mass as an basic body voluminosity, calculated as: SMM/BM, expressed in %;
5. PFI, protein-fat index, calculated as relation between Proteins (in kg) and body Fat mass (in kg) variable, expressed in kg;
6. IBC, index of body composition, calculated as relation between BMI (in $kg \cdot m^{-2}$) and percent of body fat mass (in %) variable, expressed in Index Unit (IU).

Basic anthropo-morphological variables (BH, BM and BMI) were not used in statistical analyses, but were shown in descriptive statistics and used in the discussion of the results.

Swimming Performance. Swimming performance is represented by the best results achieved by the subject in actual competitions realized after body composition measurement. The following variables were used:

1. fly50_50m and fly 50_25m, results achieved at a distance of 50m for fly stroke in long (50m) and short (25m) pool, respectively, expressed in seconds;
2. WoA_fly50_50m and WoA_fly 50_25m, the value of the swimming result in points, as an analogous quantitative value in relation to the world record (1000 points) at a distance of 50m for fly stroke in long (50 m) and short (25 m) pool, respectively, expressed numerically;
3. Fly100_50 m and fly 100_25 m, results achieved at a distance of 100 m for fly stroke in long (50 m) and short (25 m) pool, respectively, expressed in seconds;
4. WoA_fly100_50 m and WoA_fly 100_25 m, the value of the swimming result in points, as an analogous quantitative value in relation to the world record (1000 points) at a distance of 50 m for fly stroke in long (50m) and short (25 m) pool, respectively, expressed numerically.

For all swimming results, the value in analogue points (WoP point, https://www.worldaquatics.com/) form is also shown in order to classify the results on a qualitative level in relation to the current world record (standardized score of 1000 points, https://www.swimrankings.net/). Scores were not used in the statistical analyses, but were presented in descriptive statistics and used in the discussion of the results.

Statistics. Data were analyzed using descriptive analysis, correlation, linear regression methods, and principal component analysis. The following variables parameters were calculated from the descriptive statistics: MEAN – average value, SD – standard deviation, cV% - coefficient of variation, MIN and MAX – minimal and maximal variable values, and upper and lower 95% confidence intervals of the mean. Principal Component Analysis (confirmatory Factor analysis with Varimax rotation and Kaiser normalization) was used to define a set of unique spaces for used variables related to body composition and sport-specific swimming performance. Pearson's correlation analysis was used to determine the similarity and linearity between swimming performance variables and body composition variables, while linear regression analysis (LRA) was used to define the predictive relationships between swimming performance variables and the body composition variables. The level of statistical significance was defined based on criterion $p < 0.05$ (Hair *et al*., 1998). All statistical analyses were realized using the IBM SPSS 25 (IBM Corp., 2017) statistical software.

RESULTS

Table I shows all descriptive data for used variables.

Table II shows the results of the Principal Component analysis. It was found that the total measurement space contained two factors that defined 97.44 % explained cumulative variances. Two factors were extracted, with a high individual variance explanation of 51.99 and 45.44 %.

Table III shows the results of the Pearson correlation analysis. Based on the results, it can be concluded that only the SMMI variable has very strong and highly statistically significant correlations in relation to swimming performance, regardless of the length of the pool (25 or 50m) and of the swimming distance (50 or 100m).

Table I. Descriptive data results for used variables.

Variables	Mean	SD	cV%	Min	Max	95 % Confidence Interval for Mean	
						Lower Bound	Upper Bound
Age	21.2	2.4	11.3	18.0	24.5	19.3	23.0
fly50_50m	24.50	0.58	2.4	23.60	25.59	24.06	24.95
WoA_fly50_50m	753	52	6.9	659	840	712	793
Fly100_50m	54.22	1.59	2.9	52.69	57.55	52.99	55.44
WoA_fly100_50m	761	63	8.3	634	826	713	810
fly50_25m	23.85	0.78	3.3	22.85	25.13	23.25	23.59
WoA_fly50_25m	762	71	9.3	648	862	707	817
Fly100_25m	52.72	1.75	3.3	50.34	55.75	51.38	54.07
WoA_fly100_25m	748	72	9.6	629	855	693	803
BH (cm)	181.6	0.5	0.3	180.7	182.2	181.2	182.0
BM (kg)	77.3	3.4	4.4	71.9	81.1	74.7	76.9
BMI (kg/m^2)	23.45	0.94	4.0	22.02	24.50	22.73	24.17
FMI (kg/m^2)	2.72	0.33	12.1	2.31	3.28	2.47	2.65
SMMI (kg/m^2)	11.90	0.49	4.1	11.09	12.48	11.53	12.28
PBF (%)	11.60	1.16	10.0	10.15	13.44	10.71	11.54
PSMM (%)	50.76	0.66	1.3	49.69	51.77	50.25	51.27
PFI (kg)	1.54	0.17	11.0	1.29	1.76	1.41	1.67
IBC (Index Unit)	2.038	0.180	9.7	1.739	2.256	1.899	2.177

Table II. Results of factor structure of rotated component matrix of explored variables.

	Initial Eigenvalues Components	
% of Variance	51.99	45.44
Cumulative %	51.99	97.44
Variables	Factor 1	Factor 2
fly100_25m	.994	
fly50_25m	.989	
fly50_50m	.982	
SMMI	-.972	
fly100_50m	.965	
PFI		-.992
PBF		.991
PSMM		-.960
IBC		.954
FMI		.907

Figures 1 and 2 show linear regression relationships between swimming performance at distances of 50 and 100 butterfly strokes in pools of 25 and 50 m. The coefficients of determination (R^2) showed a high statistical significance of the predictive relationship between the observed variables (Fig. 1 - for 50 m distances: 84.1 % for fly50_50 m, and 94.3 % for fly50_25m, p = 0.000 respectively; Fig. 2 - for 100m distances: 81.7 % for fly100_50 m, and 91.3 % for fly100_25 m, p = 0.000 respectively).

Table III. Results of correlation analysis between body composition variables and swimming performance.

Variables		FMI	SMMI	PFI	PSMM	IBC	PBF
fly50_50m	Pearson Corr.	-.433	-.917**	.139	-.202	.167	-.172
	Sig. (2-tailed)	.244	.000	.721	.603	.667	.658
fly100_50m	Pearson Corr.	-.373	-.904**	.070	-.271	.212	-.115
	Sig. (2-tailed)	.323	.001	.858	.481	.584	.768
fly50_25m	Pearson Corr.	-.463	-.971**	.153	-.177	.193	-.182
	Sig. (2-tailed)	.209	.000	.695	.649	.618	.640
fly100_25m	Pearson Corr.	-.443	-.955**	.140	-.202	.187	-.170
	Sig. (2-tailed)	.232	.000	.719	.602	.629	.662

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

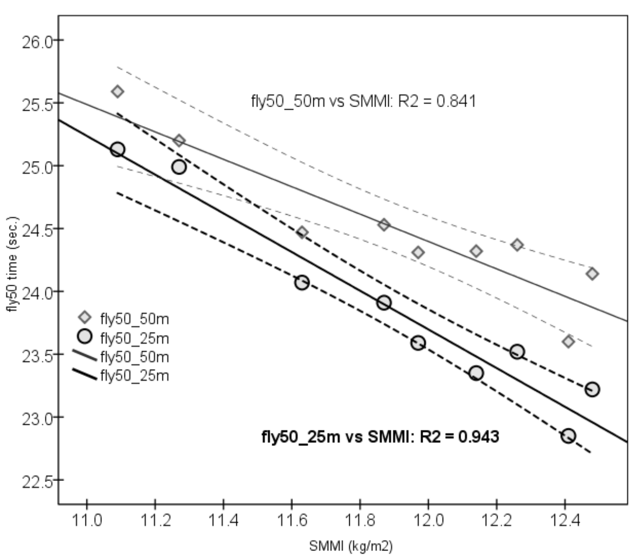

Fig. 1. Linear regression relationships between swimming performance at distances of 50 butterly strokes in pools of 25 and 50 m.

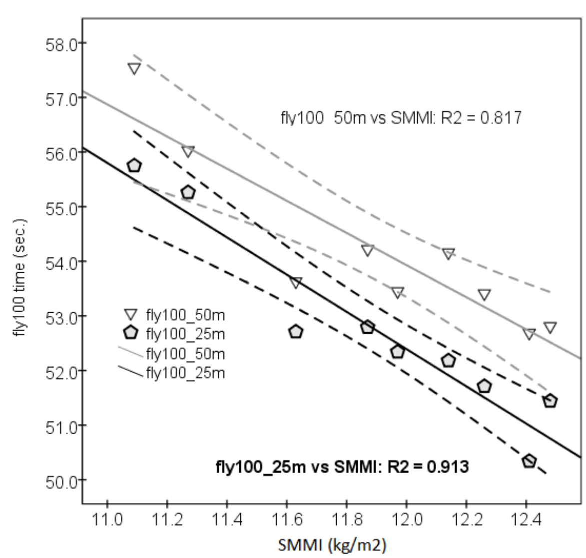

Fig. 2. Linear regression relationships between swimming performance at distances of 100 butterfly strokes in pools of 25 and 50 m.

DISCUSSION

Swimming is a cyclical sport where individuals compete under equal conditions in relation to the water, technique, distance and length of the pool. Swimming performance is influenced by a number of different factors, of which biomechanical (technique), physical (power, strength), anthropo-morphological (body characteristics and composition, body proportions and dimensions) and energy factors (characteristics of the energy systems) seem to have the greatest influence (Barbosa *et al*., 2010; Roelofs *et al*., 2017; Dopsaj *et al*., 2020; Kolmogorov *et al*., 2022; Thng *et al*., 2022; Espada *et al*., 2023).

In relation to body height (body longitudinally) of international sprinter swimmers, the examined swimmer did not belong to the category of a subject at average height [183.6 - 189.0 cm, adapted and calculated from Dopsaj *et al*. (2020), as MEAN±0.5 SD], because at the age of 24.0 years he was 182.2 cm tall. Along with other body composition characteristics, such as variables of body composition from the aspect of contractile components (PSMM and SMMI), the subject had slightly smaller amount of muscle components (50.76 vs 52.36 % and 11.90 *vs* 12.41 kg/m^2, respectively), while in the variables from the aspect of the ballast component (PBF and FMI), it had slightly more fat components (11.60 *vs* 9.82 % and 2.72 *vs* 2.35 kg/m^2, respectively) compared to the published results for international class sprint swimmers (Dopsaj *et al*., 2020).

During the 7-yr. follow-up period, the subject's swimming performance improved by 7.8 and 8.4 % in the 50 m pool, and by 9.1 and 9.7 % in the 25 m pool at 50 and 100 m fly, respectively. In the same period, the biggest changes were in the variable BM (increase by 12.1 %, from 71.9 till 80.6 kg), than in SMMI (increase by 11.9 %), from 11.09. till 12.41 kg/m^2, as well as in the FMI and BMI (increase by 11.6 %, from 2.54 till 2.84, and 10.50 %, from 22.02 till 24.33 kg/m^2, respectively). On the other hand, the variables used to define the relationship between two tissue components - indexes, as well as the relationship between individual tissue components and voluminousness (body mass), did not change nominally, i.e. there were no practical numerical changes: PFI increase for 0.2 % (from 1.518 till 1.521 kg), PBF and PSMM increases for 1.0 and 1.3 % (from 11.54 till 11.66, and 50.35 till 50.99 %, respectively).

The results of factor structure showed (Table II) the first factor is saturated by all indicators of swimming performance and with one muscle variable from the domain of body composition, while the second factor is saturated only by body composition variables. However, it must be emphasized that the SMMI variable is highly saturated in the first factor (97.2 %), which indicates the uniqueness of the space of swimming performance and the SMMI on an individual level in terms of the tested swimmer. In relation to the first factor, swimming performance variables are in reverse order in relation to SMMI, i.e. the better the performance (shorter swimming time), the higher the SMMI were.

In international-level male swimmers, it has been previously established (Dopsaj *et al*., 2020) that the three most important statistically significant correlations with sprint performance were found in variables PFI (r = 0.392, p = 0.007), IBC (r = 0.391, p = 0.007), and PSMM (r = 0.353, p = 0.016), which is not directly in line with the results from this study. It is obvious that general results at some relations between two different spaces obtained on a sample of a selected group of athletes from the same sport and specialized disciplines cannot always be directly applicable to individual cases.

The results of the correlation analysis showed that only SMMI very strongly statistically significantly correlates with swimming performance (Table III, from r = -0.917 till -0.971). In general, regardless of the length of the pool, slightly higher correlations were determined on the 50 m compared to the 100 m distances (Table III), while the absolute highest correlation was determined for 25 m and for a distance of 50 m (r = -0.971, p = 0.000). No statistically significant correlation was found for the other body composition variables (FMI, PFI, PSMM, IBC and PBF).

In other words, these results showed that on an individual (personal) level, only one aspect of body composition, as only one body qualitative characteristic in 7-yrs. follow-up period in relation to long-term swimming development, had a direct connection with the swimming performance achievement at the examined swimmers (for example - improvement from 18 to 24.5 years, from 648 to 862 WoS points and from 25.13 to 22.85 sec. for the discipline fly50_25m, Table I, MIN - MAX).

Although body composition characteristics changed during the observed period, it is evident that certain changes were non-proportional and non-linear in relation to the change in swimming performance (BM, BMI, FMI and IBC), and only one variable of body structure changed linearly and proportionally in relation to the change in swimming performance (SMMI). In general, although adaptation of body occurred more in the area of the cross-section of the body (by the square of the longitudinal body) regardless of whether it is a contractile or ballast component (SMMI, BMI, FMI), and in relation to the level of general body mass (BM), only a change in the contractile component, i.e. of skeletal muscles (SMMI) was in a statistically significant linear predictive relationship with swimming performance (Figs. 1 and 2; R^2 = 0.841, 0.943, and 0.817 and 0.913, for fly50_50 m and 25 m, and fly 100_50 m and 25m, respectively). These results indicate that the improvement in swimming performance, looking only at the aspect of long-term changes in body composition, was associated only with changes in relation to a specific body dimension (cross-sectional area) in a specific tissue (muscle - functionally related to contractile ability), which is responsible for the manifestation of physical abilities that are directly related to quality of specific motor performance i.e. for speed, explosivity, agility and strength endurance.

The results showed that the predictive relationship between SMMI and the results in the 50 and 100 m fly was higher for the performance in the 25 m pool (94.3 and 91.3 %) than for the results in the 50 m pool (84.1 and 81.7 %). It was found that SMMI is in a positive relationship with the potential of achieving better explosiveness as the ability of muscles to achieve a higher level of force in the shortest period of time (Thng *et al*., 2022; Dopsaj *et al*., 2024). It is most likely that the greater number of turns (3 compared to 1), as well as the possibility of realizing more underwater swimming distances in the 25 m pool compared to the 50 m pool (60 m compared to 30 m) provided an advantage in using of the contractile potential during swimming in the examined swimmer in a small compared to the Olympic pool (more turns, more underwater, so there is a bigger inter-pause during the race with a short local rest of the arm muscles as the main body segment for achieving efficient stroke propulsion) (Barbosa *et al*., 2010; Cortesi *et al*., 2020; Morais *et al*., 2021; Kolmogorov *et al*., 2022; Korableva *et al*., 2024).

CONCLUSION

Overall, the findings of this study provide some insight into the importance of individual monitoring of the structure and magnitude of changes in body composition, and in determining individual relations and characteristics of the connection of these changes with swimming performance in highly class swimmers over a multi-year season.

This study found that only one body composition variable had a highly statistically significant relationship over a 7-years longitudinal period with swimming performance - skeletal muscle mass index (SMMI). The determined relationship was slightly higher on the 50 m compared to the 100 m distance, as well as the results achieved in the 25 m compared to the 50m pool (shorter distance, shorter pool stronger positive relation).

Also, this research proved that the individualization of the control of the influence of changes in body composition in relation to sports performance is a necessary methodological procedure in elite sports.

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RESUMEN: El estudio tuvo como objetivo determinar la relación entre las variables que definen las características de la composición corporal y el rendimiento en natación de velocidad en velocistas mariposa masculinos de élite. El estudio se llevó a cabo durante un período longitudinal de siete años con sujetos de entre 18 y 24 años. Durante dicho período, se midieron 10 veces la composición corporal de los sujetos mediante el método de bioimpedancia segmentaria multicanal con el dispositivo InBody720, una semana antes de la competición más importante, independientemente de la longitud de la piscina (25 o 50 m) o la distancia recorrida (50 o 100 m). Los resultados del análisis de correlación mostraron que solo el índice de masa muscular esquelética (IMM) presentó una correlación estadísticamente significativa con el rendimiento en natación (r = -0,917 a -0,971), y que dicha correlación fue ligeramente mayor en la distancia de 50 m que en la de 100 m, así como en los resultados obtenidos en la piscina de 25 m en comparación con la de 50 m. No se encontró correlación estadísticamente significativa para las demás variables de composición corporal utilizadas en esta investigación (índice de masa grasa - IMG, índice proteico-graso - IFP, porcentaje de masa muscular esquelética - IMC, índice de composición corporal - IBC y porcentaje de grasa corporal - PBF). Esta investigación ha demostrado que es necesario establecer un principio de investigación según el cual el impacto de los cambios en la composición corporal y sus relaciones con el rendimiento deportivo debe comprenderse como un procedimiento metodológico individual en el deporte de élite.

PALABRAS CLAVE: Composición corporal; Rendimiento en natación; Estilo mariposa; Enfoque individual.

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