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Original Article

Correlations between chosen physiological parameters and swimming velocity on 200 meters freestyle distance before and after 5 months of training

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Abstract
In competitive sports it is unacceptable to lead a training process without regular tests and observations. Anthropometric tests are often used in contemporary sports. Body mass composition depends on energy sources which are mainly used during training and competitions. Sprinters used to have different body composition than long distances swimmers. The reason is that each of them uses different indirect energy sources and uses different percentage proportions of ST to FT muscle tissues. The aim of the study was to investigate the influence of 5-months training macrocycle on physiological parameters of swimmers aged 14,6±0,89 years. All of chosen competitors trained swimming in the same team in the same sports club. They underwent physiological test evaluating mostly their cardiovascular and respiratory parameters and maximum velocity swimming test on 200m freestyle distance. The swimming velocity test took place during Polish Junior Swimming Championships. The subjects made an effort at Monark stationary bicycle. On the basis of obtained results the following was observed: different correlation level between the swimming velocity and individual researched values, lowering the average recovery rate and increasing the average BF_{max} value on the statistically significant levels. The competitors after the training period on average shortened their recovery time. It is caused most probably by the improvement of work of blood buffers. Swimmers in competitions have to swim in numerous races at a short period of time. Carried out research shows the direction of many features and competitors' current training level. The recovery rate has changed. The mean value for the whole group decreased by *1.4s.*
Key words: swimming velocity, body physiology, training macrocycle, stationary bicycle, effort, training load.

Introduction

The physiological analysis is used to evaluate changes undergoing due to training (Górski, 2015; Kashuba et al., 2020, 2021). The training process should be constantly monitored on a current basis and periodically. The carried our analysis is adjusted to the research groups depending on age, sport discipline and advancement level (Sozański, 1999). It is an important piece of information for a coach, because interpreting the results the coach can learn if a training stimulus stimulated a positive change. There is a wide number of physiological, biochemical, anthropometric and anthropological tests which are used to monitor athletes. Depending on possibilities coaches use different direct or indirect research methods in order to constantly monitor their trainees (Sozański, 1999; Jaskólski, 2002). Nevertheless, they will both use the same direct energy source needed for muscle to contract, i.e. – ATP (Bańkowski, 2006). A significant piece of information in sports is competitor's body built, limb length and height. Anthropological measurements allow to match a competitor with proper discipline or sport competition. Unfortunately, it is very difficult because often in a training process competitor's body built and therefore the preference for chosen sport changes. Sports training is directly responsible for body development, because training loads influence it directly. Changes are often so profound that they continue for a whole life. Work of hormone glands changes depending on training load and other factors (Mędraś, 2010). Physiological tests carried out on competitors allow to evaluate their training level regarding features such as speed, endurance, strength. Thanks to many of these parameters coaches may look for weaker features at their trainees (Górski, 2015). It is one of many pieces of information which coaches must have of their trainee. Outstanding results in physiological tests not always are correlated with improved results achieved in a competition. It should be also membered that these features often change with age and that a young age competitor not always needs a high training level in order to achieve excellent result as an adult (Górski, 2015; Grygus, 2017). Coaches should remember about physiological rules and that with passing training years threshold stimuli should be increased. If special training methods were used for juveniles, it would be difficult to increase the load for adult competitors. As a result, competitors would not improve their achievements and therefore may resign from further pursuing professional sports. Due to a heavy training overload, after finishing

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sport career a reluctance to make any physical activities is observed (Kindzer et al., 2021; Lavrin et al., 2019; Mahlovanyy et al., 2021; Momot et al., 2020; Novopysmennyi et al., 2020; Petruk et al., 2021). It may result in diseases of modern civilization (Lazko et al., 2021; Sereda et al., 2020, 2021; Sydoruk et al., 2021).

The aim of the study was to investigate changes in chosen physiological values of swimmers after 5-months training macrocycle and attempt to find correlations between physiological variables and swimming velocity on 200 meters freestyle distance. Before starting the research authors stated following questions:

1. How high are the correlations between choosen physiological parameters and swimming velocity?
2. Are there any statistical differences between the researched values?
3. Will the recovery time differ after the training macrocycle?

Material and methods

The group of the study consisted of 5 swimming competitors (two males and three females) from Sports Championship School in Gdansk, Poland. All subjects trained swimming professionally since they were 10 years old. The general statistics of the study group is presented in table 1 and 2. All swimmers participated in competitions on junior national team level. The swimmers participated in 8-12 of specific training sessions in the swimming pool per week. They participated also 1-3 times per week in general training at a gym and a sports hall.

All of chosen competitors trained swimming in the same team in the same sports club. They underwent physiological test evaluating mostly their cardiovascular and respiratory parameters and maximum velocity swimming test on 200m freestyle distance. The swimming velocity test took place during Polish Junior Swimming Championships. A recovery test was carried out in a laboratory. The subjects made an effort at Monark stationary bicycle. The test started with activating a gases analyser and a two-minute resting phase. It was followed with a warm-up with steady speed of 55 to 60 rpm with training load equal to 1,5 body mass which was represented by power in Watts (W). The next stage of the test consisted of an increasing power of 25 Watts. The load increased with each minute to the moment when the subject could no longer keep the pace of 55-60 rpm. On the basis of obtained results the following was observed: different correlation level between the swimming velocity and individual researched values, lowering the average recovery rate and increasing the average BF_{max} value on the statistically significant levels.

Table 1. Anthropometric parameters
BMI – body mass index (S– September, J- January, Δ- difference)

No	Subject	Age	Body height (cm)	Body mass (kg)			BMI		
				S	J	Δ	S	J	Δ
1.	R.J.	13	179	66.8	65.8	**-1.0**	20.1	20.1	**0**
2.	D.K.	15	174	61.6	62.8	**1.2**	20.3	20.5	**0.2**
3.	K.W.	15	173	73.3	70.5	**-2.8**	24.5	233.	**-1.2**
4.	M.M.	15	169	56.5	58.6	**2.1**	19.8	20.5	**0.7**
5.	M.K.	15	169	68.9	64.6	**-4.3**	24.1	22.9	**-1.2**
	$\bar{x}$	14.6	172.8	65.4	64.5	**-1.0**	21.8	21.5	**-0.3**
	SD	0.89	4.15	6.52	4.34	**2.67**	2.33	1.51	**0.86**

Table 2. Body composition: FAT – fat tissue, FFM – fat-free body mass, TBW - total body water
(S– September, J- January, Δ- difference)

No.	Subjects	FAT (%)			FAT (kg)			FFM (kg)			TBW (kg)		
		S	J	Δ	S	J	Δ	S	J	Δ	S	J	Δ
1.	R.J.	16.6	13.4	**-3.2**	11.1	8.8	**-2.3**	55.7	57	**1.3**	40.8	41.7	**0.9**
2.	D.K.	9.5	8.6	**-0.9**	5.9	5.4	**-0.5**	55.7	57.4	**1.7**	40.8	42	**1.2**
3.	K.W.	29.9	28.5	**-1.4**	21.9	20.1	**-1.8**	51.4	50.4	**-1.0**	37.6	36.9	**-0.7**
4.	M.M.	20.6	20.6	**0**	11.6	12.1	**0.5**	44.9	46.5	**1.6**	32.9	34	**1.1**
5.	M.K.	23.8	20.8	**-3.0**	16.4	13.4	**-3.0**	52.5	51.2	**-1.3**	38.4	37.5	**-0.9**
	$\bar{x}$	20.1	18.4	**-1.7**	13.4	12.0	**-1.4**	52.0	52.5	**0.5**	38.1	38.4	**0.3**
	SD	6.85	6.84	**1.23**	5.40	4.93	**1.26**	3.96	4.16	**1.32**	2.90	3.04	**0.92**

Table 3. Evaluation of the correlation between researched features (according to A. Góralski)

r = 0	0< r <0.1	0.1 < r < 0.3	0.3 < r < 0.5	0.5 < r < 0.7	0.7 < r < 0.9	0.9 < r < 1	r=1
None	Very weak	Weak	Average	High	Very high	Almost full	Full

In order to calculate correlation between individual features and swimming speed the researchers used Spearman's Rank-Order Correlation – one of nonparametric measurements of monotonic statistical relationship between two random variables. The Statistica12 program was used to carry out the research.

Results

Analysing changes in the researched variables we can observe their individual differentiation. Comparing values of the swimming velocities achieved during competitions we can observe that the biggest increase was of 0.05 *m/s,* and the biggest increase of *0.03 m/s*. Despite the fact that the average swimming velocity of all competitors increased by *0.01 m/s,* the difference was not statistically significant (*Table 4*).

Table 4. Swimming velocity
(S– September, J- January, Δ- difference)

No.	Subjects	Swimming velocity *m/s*		
		S	J	Δ
1.	R.J.	1.41	1.43	**0.02**
2.	D.K.	1.50	1.50	**0.00**
3.	K.W.	1.44	1.43	**-0.01**
4.	M.M.	1.38	1.35	**-0.03**
5.	M.K.	1.40	1.45	**0.05**
	$\overline{x}$	1.43	1.43	**0.01**
	SD	0.05	0.05	**0.03**
		0.365		

Comparing obtained HR results, it can be observed that HR_{max} for a whole group slightly increased by *1.0 bpm* between September and January. This difference was not statistically significant. The highest individual value of HR_{max} was noted in January (*210 bpm*). The average HR_{rest} value after the training period decreased by *8 bpm.* The changes in HR_{rest} between the tests made in September and January also were not statistically significant. HR_{rest} showed a very high correlation with the swimming speed (*0.9*). The value of the correlation between HR_{max} and swimming velocity was average. It was *0.5 – see table 5*.

Table 5. Resting HR and maximum HR
(S– September, J- January, Δ- difference)

No.	Subjects	HR_{rest} *(bpm)*			HR_{max} *(s/min)*		
		S	J	Δ	S	J	Δ
1.	R.J.	113	91	**-22**	206	203	**-3**
2.	K.D.	95	83	**-12**	203	210	**7**
3.	K.W.	77	76	**-1**	176	179	**3**
4.	M.M.	108	119	**11**	203	200	**-3**
5.	M.K.	73	58	**-15**	187	187	**0**
	$\overline{x}$	93	85	**-8**	195	196	**1**
	SD	16	20	**12**	12	11	**4**
		1.483			**0.365**		

The highest individual value of VO_{2max} obtained during research was noted in September (*4.3 l/min)*. The average value for whole group decreased (-*0.2 l/min*) after the macrocycle. The difference between the results of first and second term of the tests was not statistically significant. The highest VO_{2max} value *(70.2 ml/kg/min)* belonged to K.D. This result was significantly higher than other participants of the study group. The average during second test decreased (-*4.3 ml/kg/min*). No statistical differences were noted between tests. The correlation between swimming velocity and VO_{2max}*(ml/kg/min)* was weak (0.3) – see table *6*.

Table 6. Maximum oxygen uptake capability
(S– September, J- January, Δ- difference)

No.	Subjects	VO_{2max}*(l/min)*			VO_{2max}*(ml/kg/min)*		
		S	J	Δ	S	J	Δ
1.	R.J.	4.0	3.9	**-0.1**	54.4	50.3	**-4.1**
2.	K.D.	4.3	4.1	**-0.2**	70.2	65.1	**-5.1**
3.	K.W.	3.0	3.1	**0.1**	42.2	44.6	**2.4**
4.	M.M.	3.1	2.7	**-0.4**	55.3	45.2	**-10.1**
5.	M.K.	3.5	3.0	**-0.5**	50.6	46.1	**-4.5**
	$\overline{x}$	3.6	3.4	**-0.2**	54.5	50.3	**-4.3**
	SD	0.5	0.5	**0.2**	9.1	7.7	**4.0**
		1.618			**1.753**		

The highest individual power achieved in both test was *345W*. The mean power value increased by *14W* after the training period. This variable decreased only in one case (-*20W*). There were no statistically significant differences between the tests. The competitor K.D. had the highest result of power per body mass in September *(5.60W)*. The average value for the whole group in both test did not change a lot. The highest power increase was 1 *W/kg*, while the highest power decrease was -*0.50 W/kg.* The results obtained during tests were not statistically significant. Both the correlation between maximum power and swimming speed and maximum power per kilogram of body mass and swimming velocity was ranked as „high" (*0.7*) – see *table 7*.

Table 7. Power test results
(S– September, J- January, Δ- difference)

No.	Subjects	Max power (*W*)			Max power (*W/kg*)		
		S	J	Δ	S	J	Δ
1.	R.J.	250	270	**20**	3.70	4.10	**0.40**
2.	K.D.	345	345	**0**	5.60	5.50	**-0.10**
3.	K.W.	230	255	**25**	3.10	3.60	**0.50**
4.	M.M.	260	240	**-20**	4.60	4.10	**-0.50**
5.	M.K.	250	295	**45**	3.60	4.60	**1.00**
	$\overline{x}$	267	281	**14**	4	4	**0**
	SD	40	37	**22**	1	1	**1**
		1.278			**0.809**		

Highest noted resting lungs ventilation per minute (VE) was *17.0 l/min*, and the smallest -*11.0 l/min.* The mean value decreased by *0.6 l/min* after the training period*.* There were no statistically significant differences between tests in September and January. Subjects' resting breathing pattern (BF) during first measurement was on average *18.6 breathes/min,* during the second *19.2 breathes/min,* which means an increase of *0.6 breathes/min.* The results noted in both tests were not statistically significant. The average VE_{max} increased by *10.6 l/min*. Only in one case the result showed a downward trend (*-3 l/min*)*.* The biggest VE_{max} increase was *24.0 l/min.* The differences between results of the tests in September and January were not statistically significant. The highest BF_{max} value was obtained by the competitor K.D. - *56.0 breathes/min.* On average the research group obtained BF_{max} result higher by *6.2 breathes/min* in the second test*.* The difference was statistically significant – see *table 8*. The correlation force between swimming speed and variables: VE (0.1), BF (0.3), VE_{max} (0.1) and BF_{max} (0.1) was very weak or weak.

Table 8. Lung ventilation (VE) and breathing pattern (BF)
(S– September, J- January, Δ- difference) *p<0.5

No.	Subjects	*VE (l/min) resting*			*BF (breathes/min) resting*		
		S	J	Δ	S	J	Δ
1.	R.J.	11.0	13.0	**2.0**	15.0	13.0	**-2.0**
2.	K.D.	17.0	13.0	**-4.0**	13.0	19.0	**6.0**
3.	K.W.	15.0	15.0	**0.0**	21.0	23.0	**2.0**
4.	M.M.	17.0	17.0	**0.0**	31.0	26.0	**-5.0**
5.	M.K.	13.0	12.0	**-1.0**	13.0	15.0	**2.0**
	$\bar{x}$	14.6	14.0	**-0.6**	18.6	19.2	**0.6**
	SD	2.6	2.0	**2.2**	7.7	5.4	**4.2**
		0.535			**0.405**		
No.	Subjects	*VE_{max} (l/min)*			*BF_{max} (odd./min)*		
		S	J	Δ	S	J	Δ
1.	R.J.	120.0	124.0	**4.0**	53.0	55.0	**2.0**
2.	K.D.	150.0	167.0	**17.0**	54.0	56.0	**2.0**
3.	K.W.	111.0	135.0	**24.0**	44.0	52.0	**8.0**
4.	M.M.	100.0	97.0	**-3.0**	47.0	53.0	**6.0**
5.	M.K.	116.0	127.0	**11.0**	38.0	51.0	**13.0**
	$\bar{x}$	119.4	130.0	**10.6**	47.2	53.4	**6.2**
	SD	18.7	25.1	**10.6**	6.6	2.1	**4.6**
		1.753			**2.023***		

The average resting RQ decreased by *0.04*. Only R.J. showed an increase of this feature. Rest of the subjects showed a downward trend. The highest RQ noted during the test (*1.21)* was obtained by two competitors: D.K. and M.M. The group average increased slightly (*0.01*). The results of both tests did not show a statistically significant difference. The correlation between resting RQ and swimming velocity was very weak (0.1). While there is an almost full correlation (*0.97*) between maximum RQ and swimming velocity.

Table 9. Respiratory quotient RQ
(S– September, J- January, Δ- difference)

No.	Subjects	*RQ resting*			*RQ maximum*		
		S	J	Δ	S	J	Δ
1.	R.J.	0.77	0.78	**0.01**	1.14	1.20	**0.06**
2.	D.K.	0.85	0.82	**-0.03**	1.21	1.21	**0.00**
3.	K.W.	0.95	0.83	**-0.12**	1.20	1.18	**-0.02**
4.	M.M.	0.95	0.94	**-0.01**	1.21	1.17	**-0.04**
5.	M.K.	0.90	0.87	**-0.03**	1.24	1.30	**0.06**
	$\bar{x}$	0.88	0.85	**-0.04**	1.20	1.21	**0.01**
	SD	0.08	0.06	**0.05**	0.04	0.05	**0.05**
		1.618			**0.730**		

The average time to achieve maximum number of heart contractions increased by *62.2s*. Only in case of one competitor (M.M.) the time decreased by *4.0s*. The biggest difference between two tests was 109.0s *(K.W.)*. Despite significant individual differences, the change between average results of all subjects were not statistically significant. The longest recovery time to HR=150 bpm was noted during tests in September (*134.0s*). The mean value for whole group decreased by *1.4s*. The average values obtained during test were not statistically significant– *see table 10*. The correlation between time to reach HR_{max} and swimming velocity was weak (*0.3*). While correlation between the recovery time and swimming velocity was on the average level (*0.5*).

Table 10. Time to reach HRmax and recovery time after the test to reach HR=150 bpm
(S– September, J- January, Δ- difference)

No.	Subjects	Time (s) to reach HR_{max}			Recovery time (s) to reach 150 bpm		
		S	J	Δ	S	J	Δ
1.	R.J.	739	784.0	**45.0**	120.0	100.0	**-20.0**
2.	D.K.	905	966.0	**61.0**	62.0	100.0	**38.0**
3.	K.W.	683	792.0	**109.0**	41.0	40.0	**-1.0**
4.	M.M.	784	780.0	**-4.0**	134.0	110.0	**-24.0**
5.	M.K.	750	850.0	**100.0**	80.0	80.0	**0.0**
	$\bar{x}$	772.2	834.4	**62.2**	87.4	86.0	**-1.4**
	SD	82.7	78.8	**45.5**	39.0	27.9	**24.6**
		1.753			**0.365**		

Discussion

Monitoring of changes undergoing during workouts is an inseparable aspect of a training. That way the direction of changes and competitors' progress can be measured. In professional sports many general and specialistic tests are carried out. However, it should be remembered that improving individual features not always correlates with improving sport results (Sozański, 1999). Many physiological tests helps in defining training loads in a macrocycle. Therefore, they should be carried out periodically in order to check a long-time direction of changes. These tests should be matched with the character of work carried out during sport competitions, because there will be probably bigger correlation between results obtained in a laboratory and the results achieved in competitions (Rakowski, 2014). As t*able 4* presents swimming velocity does not change significantly after a workout. It is interesting. At this age competitors should constantly improve their results. The training should consist of smaller stimuli caused by challenging workouts. It is a significant method to prevent overtraining both in physical and physiological way. Sportsman should not start demanding and regular training too early (Rakowski, 2014). The effect of endurance training is slowing down the resting heart rate. It is a consequence of the work of the parasympathetic system, which slows down the heart rate and causes heart muscle to overgrow (so called sportsman heart) (Górski, 2015). Analysing obtained results it can be concluded that work of cardiovascular system improved slightly.

There were no big differences between the tests – which may suggest a lack of overtraining. One of the methods to monitor overtraining is to constantly monitor HR_{rest}. Body mass composition after finishing the training had slightly changed, but it was not statistically important. The direction of undergoing changes was positive for the swimmers – their fat tissue showed a downward trend which over time can have a positive influence on competitors' motoric skills while in competition. It also lowers the pressure on the skeleton, joints and muscles during specialistic training in water. Similar changes were observed in the research carried out by Figueiredo and colleagues (2016), in which the research procedure lasted twelve weeks. The research group consisted of obese people undergoing HIIT training. Another evidence confirming that the strength-resistance training has a significant influence on body composition was presented Kim (2016). During his research on a group of students, he obtained similar results. A high intensity interval training is often used for swimmers. High intensity exercises lower body fat both in case of people with high and low training level. Proper diet is the factor which increases the speed of this change. Maximum oxygen consumption – $VO2_{max}$ after the training macrocycle did not change in a statistically significant way. It may be caused by too small or poorly chosen training stimulus. It is unknown if the coach tried to improve this feature at that time or maybe focused on anaerobic training. The results of this variable correlates on a weak level with the swimming velocity. It may mean that the main sources for ATP synthesis in sport competitions are not aerobic but anaerobic. Figueiredo and colleagues (2016) proved that a high intensity interval training used over 12-week period has significantly increased Vo_{2max} for a poorly trained people. Similar conclusions were reached in their research by Kim and Han (2016) showing that the force-resistance training in a 3-month period will have a significant influence on improving performance. From the results obtained during the research one can conclude, that the power showed strong correlation with swimming velocity.

Therefore, increasing this feature should have a positive influence on results achieved in short distance swimming competitions from 50 to 100 meters. Moreover, in case of short and medium distances the maximum power is a better indicator than $VO2_{max}$ to evaluate performance. Observing the directions of changes obtained after the training macrocycle it may be concluded that during the macrocycle many HIIT exercises were used. Georges Jabbour and colleagues (2017) show, that high intensity training lasting 6 weeks for young and older people increases power. On this basis it can be concluded that after such training at each training level an increase in power can be expected. In case of people with lower training level the power increase will be higher than in case of people with high training level. Lungs ventilation per minute is one of components of breathing.

It shows the amount of air which goes through lungs while resting and at maximum effort (Górski, 2015). The carried out research shows that the group average at rest decreased. This may indicate higher number of capillaries in pulmonary alveolates and higher amour of haemoglobin. Probably competitors did not need such big filtration in order to have high oxygen saturation. It is interesting that the direction of changes while in effort was the opposite.

Conclusions

The competitors after the training period on average shortened their recovery time. It is caused most probably by the improvement of work of blood buffers. Swimmers in competitions have to swim in numerous races at a short period of time. Therefore, this information is very important. The recovery rate may often be the key to start in another race at a sporting arenas. Carried out research shows the direction of many features and competitors' current training level. On the basis of obtained results the authors answered the following research questions:

1. The correlation level between the swimming velocity and individual variables was varied and equal: rest HR (bpm) – very high (0.9), maximum HR (bpm)– none (0.05), VO2max (l/min) – weak (0.3), VO2max (ml/kg/min) – weak (0.3), max power (W) – high (0.7). Max power (W/kg) – high (0.7), rest VE (l/min)– very weak (0.1), rest BF (br./min)– weak (0.3), maximum VE (l/min)– very weak (0.1), maximum BF (br./min)– very weak (0.1), rest RQ– very weak (0.1), maximum RQ– almost full (0.9), time (s) to reach HR max – weak (0.3) and recovery time (s) to reach 150 bpm – average (0.5).
2. The average value of BF_{max} as the only one of the researched features increased in a statistically significant way.
3. The recovery rate has changed. The mean value for the whole group decreased by *1.4s.*

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Conflict of interests

The authors declare that there is no conflict of interests.

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