VARIABILITY IN SWIMMERS' INDIVIDUAL KINEMATICS PARAMETERS VERSUS TRAINING LOADS

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ABSTRACT: The aim of the study was to investigate individual relationships between the training loads and kinematics parameters in macro cycle period of the swimmers' training program. Two experienced butterfly swimmers: male (age 18) and female (age 16) took part in the study. The training program was equal for both. The experiment consisted of swimming 25-m butterfly eight times (start every 1 min) with increasing speed in each successive repetition. The attempts were carried out five times, in 6-7-week intervals, between September 2006 and April 2007. The swimming technique was evaluated according to "Stroke Mechanics Test" by David Pyne. Each attempt was video-recorded. The analysis of the swimming technique revealed individual differentiations. The male swimmer consequently increased his maximal velocity and stroke rate. The correlation between the maximal velocity and accumulation of training volume was statistically significant (Pearson's coefficient = 0.9394, $p<0.05$). Stroke length decreased proportionally, while the highest stroke index value was achieved in the third attempt. In the female swimmer, values of maximal speed, stroke length and stroke index did not increase essentially in the whole experiment. The most advantageous proportions among kinematics parameters were observed in the third attempt, then these values decreased. Training loads applied to the examined subjects appeared to be effective only in the case of the male swimmer. The training program for the female athlete should have been changed after the third attempt. Butterfly-oriented technique exercises in lower intensity, individual medley and freestyle tasks would have been recommended in that case.

KEY WORDS: swimming, stroke rate, stroke length, training volume

INTRODUCTION

Because of multitude of factors that decide on the outcomes in swimming, the problem of individualization is still a vast exploring field. Methods available nowadays are being constantly verified and selected to answer current needs of the whole training process. A continuously repeating problem is the selection of right volume and work intensity proportions [1]. It is these proportions that mostly play the key role not only in programming training units but also selecting athletes for future distance specialization. The development of swimming technique led to its assessment based on kinematics variables. In recent years, to the European and world class competitions' protocols, except the time of covering each distance, the values of average velocity (v), stroke length (SL), stroke rate (SR) and stroke index (SI) are also added. While working on the development of swimming technique, age and level of sporting abilities should be taken into consideration [7]. Younger groups, presenting lower level will have different goals to those of higher level and more experience. Considering individual swimming technique variability for training purposes of every athlete, the elementary components of swimming technique, which are: stroke length, velocity and stroke index towards swimming speed, should be tested regularly [11,18].

The aim of this research was to describe the influence of training load on individual swimming technique variability in one macro cycle training period.

Two questions were to be answered in this study: Did the training loads cause the same changes in velocity and swimming technique of both subjects? Which kinematics parameters were correlated most with maximal velocity in the examined subjects?

MATERIALS AND METHODS

With the approval of institutional ethics, two butterfly swimmers: male (age 18) and female (age 16) took part in the study. They were both finalists of Polish Championships in 2006. The attempts were carried out five times, in 6-7-week intervals, between September 2006 and April 2007. Throughout the all-year training the program was equal for both. To asses the swimming technique, David Pyne's "Stroke Mechanics Test" [12] has been used, with all necessary modifications that enabled testing on 25-meter swimming pool.

TABLE 1. ACCUMULATION OF TRAINING VOLUME IN SUCCESSIVE MESOCYCLES, SEASON 2006/2007

mesocycle	∑ orientated [km]	∑ special [km]	∑ orientated-special [km]
1.	157.9	63.2	221.1
2.	414.1	212.9	627.0
3.	838.1	385.1	1223.2
4.	1033.8	456.8	1490.6
5.	1194.7	546.7	1741.4

TABLE 2. PEARSON'S PRODUCT MOMENT CORRELATION (R) BETWEEN TRAINING LOADS AND MAXIMAL SWIMMING VELOCITY IN EXAMINED SUBJECTS

	vmax, female	vmax, male
∑ orientated [km]	0.301	0.857*
∑ special [km]	0.251	0.938*
∑ orientated-special [km]	0.286	0.939*

Legend: * - <0,05

The experiment consisted of swimming 25-meter butterfly eight times (start every 1 minute) with increasing speed in each successive repetition. Repetitions were to be done with steady pace, after taking off from the pool wall (omitting the starting jump). Sony 8-mm Hi-8 (25 Hz) video camera was used to register the swimming technique. The time of three full movement cycles was measured in the centre part of the pool.

Calculations were made according to following formulas:

SR = 60 x 3/tSR, SR – stroke rate, tSR – time of 3 cycles

V = S/t, V- velocity, S- distance, t- time

SL = V x 60/SR, SL- stroke length

SI = V x SL, SI- stroke index

Stroke rate, stroke length and stroke index of the technique were calculated by Microsoft Excel program. Statistics (mean, standard deviation, Pearson product moment correlation, linear regression equation) were done by using of Microsoft Excel 2000, too.

Throughout the whole year, the training registration was based on intensity and volume of training loads [8]. Analysis of the influence of training loads on individual swimming technique was done basing on volume accumulation effect on every range of intensity. The volume of training load done previously was added to each intensity range of every following mesocycle.

RESULTS

Before the study, the training loads of analyzed period were precisely classified in energy categories. In this study, the mileage (expressed in kilometers) has been acknowledged as an indicator of the training volume. It has been assumed, that the training volume of each mesocycle influences the next one; therefore, the mileage of analyzed period was summed up (Table 1). What was taken into consideration at this point was, orientated and special character loads and its sum.

TABLE 3. FEMALE'S INDIVIDUAL VALUES OF VELOCITY, STROKE RATE, STROKE LENGTH AND STROKE INDEX IN EACH 8X25M TRIAL

number of trial	kinematics parametres	repetitions 1	2	3	4	5	6	7	8
1.	v [m/s]	1.27	1.27	1.33	1.34	1.33	1.36	1.40	1.49
	SR [c/min]	41.9	41.3	42.7	42.5	43.7	45.0	47.1	53.3
	SL [m]	1.82	1.84	1.88	1.90	1.83	1.82	1.79	1.68
	SI [m*m/s]	2.30	2.33	2.51	2.55	2.45	2.48	2.51	2.49
2.	v [m/s]	1.16	1.18	1.19	1.27	1.30	1.34	1.35	1.46
	SR [c/min]	40.9	40.4	40.2	42.1	42.1	45.0	47.4	52.3
	SL [m]	1.71	1.75	1.77	1.82	1.85	1.79	1.71	1.67
	SI [m*m/s]	1.99	2.07	2.10	2.31	2.39	2.39	2.32	2.44
3.	v [m/s]	1.16	1.19	1.24	1.34	1.36	1.40	1.42	1.51
	SR [c/min]	39.8	40.9	42.1	45.2	47.6	49.5	49.7	53.9
	SL [m]	1.75	1.74	1.77	1.78	1.71	1.70	1.72	1.68
	SI [m*m/s]	2.04	2.07	2.20	2.40	2.33	2.39	2.44	2.55
4.	v [m/s]	1.18	1.27	1.32	1.35	1.39	1.41	1.46	1.50
	SR [c/min]	41.3	43.3	44.1	46.6	47.9	48.6	52.0	54.5
	SL [m]	1.72	1.76	1.79	1.74	1.74	1.74	1.68	1.65
	SI [m*m/s]	2.03	2.24	2.36	2.34	2.41	2.46	2.46	2.48
5.	v [m/s]	1.25	1.26	1.30	1.36	1.41	1.43	1.43	1.48
	SR [c/min]	41.3	42.9	44.3	47.1	50.0	50.6	52.3	54.5
	SL [m]	1.82	1.77	1.76	1.74	1.69	1.70	1.64	1.63
	SI [m*m/s]	2.27	2.24	2.29	2.37	2.39	2.42	2.36	2.41
Mean ± SD	v [m/s]	1.21 ± 0.05	1.23 ± 0.05	1.28 ± 0.06	1.33 ± 0.04	1.36 ± 0.05	1.39 ± 0.04	1.41 ± 0.04	1.49 ± 0.02
	SR [c/min]	41.0 ± 0.76	41.7 ± 1.26	42.7 ± 1.69	44.7 ± 2.34	46.3 ± 3.27	47.7 ± 2.59	49.7 ± 2.47	53.7 ± 0.94
	SL [m]	1.76 ± 0.05	1.77 ± 0.04	1.80 ± 0.05	1.79 ± 0.07	1.77 ± 0.07	1.75 ± 0.05	1.71 ± 0.05	1.66 ± 0.02
	SI [m*m/s]	2.13 ± 0.15	2.19 ± 0.12	2.29 ± 0.15	2.39 ± 0.09	2.39 ± 0.04	2.43 ± 0.04	2.42 ± 0.08	2.47 ± 0.05

TABLE 4. PEARSON'S PRODUCT MOMENT CORRELATION BETWEEN MAXIMAL VELOCITY AND STROKE RATE, STROKE LENGTH, STROKE INDEX IN EXAMINED SUBJECTS

	r		
	vmax / SR	vmax / SL	vmax / SI
female	0.645	0.192	0.792
male	0.849	-0.524	0.200

Group of orientated exercises includes variety of swimming tasks, not connected strictly to athlete's typical stroke and distance. These exercises are realized in the wide range of intensity. Special exercises are directed on specific distance and stroke; anaerobic intensity is preferred here mostly.

Correlation of the accumulation effect with swimming velocity registered during the last repetition of trial was different for both subjects. The force of dependence in the male swimmer's case was marked as very high for orientated loads and almost full for special loads and their sum (Table 2).

In the female athlete's case, the correlation between the volume of completed training work and maximum velocity did not show as high dependence as in the male's case. The force of relation turned out to be weak (Table 2).

While analyzing variability of swimming technique, its individual diversity has been noticed. In the female athlete, the value of velocity, stroke length and stroke index were on similar level in 8th repetition

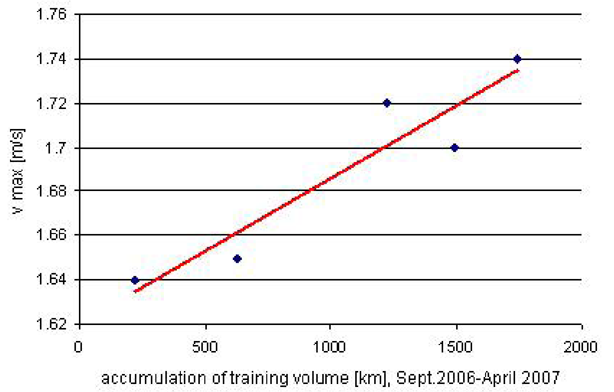

FIG. 1. MAXIMAL VELOCITY VERSUS TRAINING VOLUME IN MALE SWIMMER

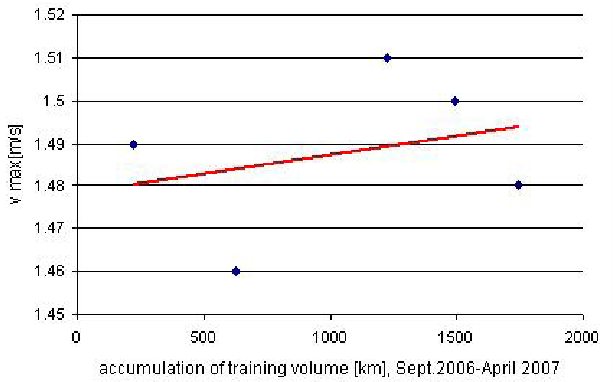

FIG. 2. MAXIMAL VELOCITY VERSUS TRAINING LOADS IN FEMALE SWIMMER

TABLE 5. MALE'S INDIVIDUAL VALUES OF VELOCITY, STROKE RATE, STROKE LENGTH AND STROKE INDEX IN EACH 8X25M TRIAL

number of trial	kinematics parametres	repetitions							
		1	2	3	4	5	6	7	8
1.	v [m/s]	1.29	1.35	1.44	1.48	1.53	1.55	1.62	1.64
	SR [c/min]	39.1	40.5	44.1	45.5	47.9	50.0	52.9	54.2
	SL [m]	1.98	2.00	1.95	1.96	1.92	1.86	1.83	1.81
	SI [m*m/s]	2.56	2.71	2.81	2.90	2.94	2.88	2.96	2.97
2.	v [m/s]	1.43	1.45	1.52	1.56	1.59	1.60	1.63	1.65
	SR [c/min]	42.3	43.9	46.9	48.9	50.3	50.8	50.6	52.9
	SL [m]	2.02	1.99	1.95	1.92	1.90	1.89	1.93	1.87
	SI [m*m/s]	2.89	2.89	2.97	2.99	3.01	3.03	3.15	3.09
3.	v [m/s]	1.33	1.42	1.45	1.51	1.52	1.63	1.63	1.72
	SR [c/min]	38.8	41.3	43.3	44.6	45.5	49.5	51.4	55.6
	SL [m]	2.05	2.06	2.01	2.04	2.01	1.98	1.90	1.86
	SI [m*m/s]	2.72	2.91	2.91	3.08	3.05	3.23	3.09	3.20
4.	v [m/s]	1.39	1.44	1.50	1.57	1.60	1.62	1.64	1.70
	SR [c/min]	42.1	43.3	44.8	48.4	50.6	51.4	52.3	56.3
	SL [m]	1.98	1.99	2.01	1.95	1.90	1.89	1.88	1.82
	SI [m*m/s]	2.75	2.86	3.02	3.05	3.03	3.05	3.09	3.10
5.	v [m/s]	1.45	1.59	1.64	1.68	1.72	1.74	1.76	1.74
	SR [c/min]	41.7	45.9	50.6	52.9	54.2	57.3	59.2	60.8
	SL [m]	2.08	2.08	1.95	1.91	1.90	1.82	1.79	1.71
	SI [m*m/s]	3.02	3.30	3.20	3.20	3.26	3.17	3.16	2.97
Mean ± SD	v [m/s]	1.38 ± 0.07	1.45 ± 0.09	1.51 ± 0.08	1.56 ± 0.08	1.59 ± 0.08	1.63 ± 0.07	1.66 ± 0.06	1.69 ± 0.04
	SR [c/min]	40.8 ± 1.68	43.0 ± 2.14	45.9 ± 2.92	48.1 ± 3.31	49.7 ± 3.27	51.8 ± 3.18	53.3 ± 3.43	56.0 ± 3.00
	SL [m]	2.02 ± 0.04	2.02 ± 0.04	1.97 ± 0.03	1.95 ± 0.05	1.92 ± 0.05	1.89 ± 0.06	1.87 ± 0.06	1.81 ± 0.06
	SI [m*m/s]	2.79 ± 0.17	2.93 ± 0.22	2.98 ± 0.14	3.05 ± 0.11	3.06 ± 0.12	3.07 ± 0.13	3.09 ± 0.08	3.07 ± 0.10

of every trial. Looking at the effects of the whole year training, a decrease of velocity, stroke length and stroke index is easily noticed. A slight improvement in stroke rate accompanying the maximum swimming velocity can be also observed. However, the best results were obtained at the 3rd test, during which the female athlete maintained a high stroke frequency at the same time keeping the highest velocity, stroke length and index values of all tests (Table 3).

The analysis of correlation of swimming velocity towards the stroke rate, stroke length and stroke index achieved in the last repetition of 8x25 trial proves that the least important component of female swimmer's technique to achieve maximal speed was stroke length. Simultaneously, a high correlation between velocity and stroke rate was noticed, as well as between velocity and stroke index (Table 4).

Male swimmer's results showed a very high correlation between speed and frequency. It also relates to the stroke length. However, this correlation is in reverse. Weak correlation force is registered between velocity and stroke index (Table 4).

As well as in the female athlete's case, the male's results proved the 3rd test to be the most successful. Here, it was also possible to maintain a significant stroke length, which was important for the highest stroke index in the last trial (Table 5).

What is worth paying attention to, is the regression analysis of the maximum swimming speed towards the training load accumulation effect. As in the female athlete the liaison did not reveal any statistical importance (Fig. 2), the male athlete's case showed a strong relation between the two variables (Fig. 1). This relation was statistically significant at $p<0.05$ level.

DISCUSSION

The applied training loads turned out to be effective for developing maximum speed for the male swimmer. The stroke index value did not show any changes, because the speed increase was connected with the stroke rate and not the stroke length. Female athlete's results did not prove any correlation between training loads and swimming technique in any of the trials.

Swimming technique analysis in reference to applied training loads gives the necessary information on the affection efficiency of the training means [16]. Although the same training load has been used in both swimmers, a better effect of the whole year training was achieved by the male athlete. The training fulfilled the goals in developing maximum velocity. At the same time, the swimmer showed the reserves which are possible in his technique skills.

If the training was to be continued with the female athlete, the first thing to be changed would be the training loads to increase the efficiency of the training. No significant increase in kinematics parameters was registered here. The most expected changes took place until the 3rd test, whereas the two last mesocycles showed increase in stroke rate only. However, that was not enough to improve or even maintain the maximum velocity.

The training loads directed to develop maximum velocity must consider the stroke length and the frequency, optimum and individual for every swimmer [4]. As in the male swimmer's case these values were correctly adapted, some significant changes should have been made in the female swimmer work-out starting with the 4th mesocycle. However the value of maximum velocity may ensure the coach of correctly chosen training load, a detailed analysis of all repetitions of the 3rd trial proves that this may occur due to major economization of the swimming technique. What proves it is a small difference (0.1m) between the highest stroke length reached in the 4th and the last repetition. Similar observations were made by Chatard, Lavoie and Lacour [3]. Introducing too much loads in high intensity leads to disturbing proportions between aerobic and anaerobic exercises. This may lead to decrease the level of endurance in the following training period and may also lead to increase of fatigue in repeated exercises. This is likely to appear in exercises which involve maximum velocity on short distances and distances over 100 m. Research results available in scientific literature do not show unambiguous solutions to this problem. The research concerning the influence of repeated sprint sets on kinematics parameters in butterfly shows that stroke length remains relatively unchanged while decreasing swimming velocity and stroke rate [10]. Other research showed that fatigue lead to decrease of peak power and the peak power frequency [15]. The influence of increasing tiredness on swimming technique was observed also by other researchers. Results of those better trained athletes (Olympic competitors) showed smaller differences in stroke length and stroke rate between successive swimming zones, than those less well trained (national level competitors) [6]. Thus, in other research carried out during training macro cycle of teenage swimmers, no significant changes have been noticed in kinematics values, but in anthropometric values [9].

CONCLUSIONS

Minding the example presented in this study, it seems suitable to improve stroke length at low swimming velocity in the female athlete. Therefore it is advisable to lower training intensity to the level of 70-90% VO2max [5]. Secondly, it should not be forgotten that butterfly swimmer needs more and bigger stimuli to develop stroke efficiency [2]. However hard this may seem to realize, introducing freestyle and medley exercises should help maintaining the endurance which should positively influence developing the stroke length [17].

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