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THE SWIMMING INDEX AND LACTIC ACID IN HIGHER
AEROBIC EFFORT

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Abstract

Introduction: Swimming represents a physical activity that involves moving the body through water and is characterised by cyclical arm and leg movements coordinated with breathing. The concept of total training brings a new approach to training factors, with global repercussions on the performance components. The time pressure put on coaches and athletes brings into focus the use of sprint means to improve higher aerobic endurance, thus reducing the training volume (number of hours and kilometres). Knowing the metabolic effort zones encountered in the training of swimmers and the subtle connections between these zones allows improving the effects of training through apparently paradoxical means. Nowadays, field specialists talk about aerobic and anaerobic powers and capacities, about the development of VO₂ max through alactacid and lactacid anaerobic efforts. Hypothesis: Using short-term sprint exercises can lead to an increase in aerobic endurance (VO₂ max). The research subjects are 15 senior athletes, members of the Tunisian National Swimming Team. Methods: The research is focused on the ascertaining pedagogical experiment with one variable. Maximum oxygen consumption was assessed by applying the T-2000 test correlated with the items: swimming index and post-exercise lactic acid value. Mathematical and statistical methods: arithmetic mean, standard deviation, Pearson correlation coefficient, coefficient of determination (r²), graphical representation. Results: The analysed data highlight a strong correlation between the two parameters (swimming index and lactic acid), $r = 0.869$, which shows a very strong association. Therefore, the use of short-term sprint exercises can increase aerobic endurance; thus, the research hypothesis is validated.

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Keywords: Swimming index, lactic acid, T-2000 test, higher aerobic effort.



1. Introduction

Swimming represents a physical activity that involves moving the body through water and is characterised by cyclical arm and leg movements coordinated with breathing. Specialists in the field show that maximum aerobic endurance (MAE) delays exhaustion of the swimmer's body through means achieved in percentages of VO_2 max (maximum oxygen consumption), MAP (maximum aerobic power) or MAS (maximum aerobic speed); all these parameters are influenced by the energy potential, the cardiac cost of the body, but also by the technical efficiency, the volume of swimming over a given distance (Guedj, Brunet, Girardier, & Moyen, 2006). Influencing performance according to the quantification and efficiency of the technique can be achieved by calculating the swimming index, namely by multiplying the swimming speed by distance per stroke (DPS). This index assumes that, at a given speed, the athlete who swims with the highest DPS value has the most efficient swimming technique (Costill, Maglischo, & Richardson, 1994). The concept of total training brings a new reorientation/approach to training factors, with global repercussions on the performance components. The time pressure put on coaches and athletes brings into focus the use of sprint means to improve higher aerobic endurance, thus reducing the training volume (number of hours and kilometres). The new concept of High-Intensity Interval Training (HIIT)/ 10-20-30 Interval Training Model, which highlights the maximum effort intensity reached through short-term ultrafast sprints, has an impact on improving higher aerobic exercise capacity/ MAE, where the swimming index and lactic acid production are parameters that, if correlated, can provide data about the specificity of the research (Kenney, Wilmore, & Costill, 2015). Knowing the metabolic effort zones encountered in the training of swimmers and the subtle connections between these zones allows improving the effects of training through apparently paradoxical means. Nowadays, field specialists talk about aerobic and anaerobic powers and capacities, about the development of VO_2 max through alactacid and lactacid anaerobic efforts.

2. Problem Statement

The stimulation of higher aerobic exercise capacity through sprint-specific anaerobic means generates problems, questions, permissive and restrictive assertions.

The connexion of the vectors: exercise intensity, swimming index and lactic acid generates the future premise and hypothesis of the research.

3. Research Questions

Are there connections between the lactic acid accumulation and the swimming index calculation?
Can the use of short-term sprint exercises determine the increase in higher aerobic endurance?

4. Purpose of the Study

Identification of the means and methods to invalidate or confirm the responses to the research problems/hypothesis. This is for the first time in the world that a comparison is made between the two parameters.

5. Research Methods

5.1. Hypothesis

Using short-term sprint exercises can lead to an increase in aerobic endurance (VO_2 max).

5.2. Research subjects

15 high-ranking male athletes, aged between 20 and 21 years, members of the Tunisian National Swimming Team. Testing and training took place in the Olympic pool (50m) in Rades, Tunisia.

5.3. Research methods

The research is focused on the ascertaining pedagogical experiment with a single variable. Maximum oxygen consumption was assessed by applying the T-2000 test correlated with the items: swimming index and post-exercise lactic acid value. Initial testing was applied on 12 February 2015, and final testing on 19 August 2015. The T-2000 test was administered at the beginning and the end of the 6-month experimental period; meanwhile, the repeated sprint test, consisting of a maximal sprint test over the distance of 50m, 2 series of 6x50m crawl, with 10-second breaks and departure every 5 minutes, was applied twice a week. Mathematical and statistical methods: arithmetic mean, standard deviation, Pearson correlation coefficient, coefficient of determination (r^2) and graphical representation (Popa, 2008).

5.4. Description of tests and studied parameters

5.4.1. Tests

- repeated sprint test: the test 2 x (6x50m freestyle) consists in swimming the distance of 50m with a 100% intensity, after a preliminary specific warm-up; the break between repetitions is 10 seconds, and between series, 5 minutes;

- T-2000 test: it is aimed to assess higher aerobic capacity and consists in swimming as fast as possible (80-85% intensity) the distance of 2000m, provided that the intermediate times recorded per 100m are the closest possible to each other. Generally, a preliminary test is needed, so that the athlete gets used to the pace of the race. It should be noted that a difference of more than 4 seconds between the best and poorest 100m swim leads to inaccurate test results. The total time and average time per 100m swim are entered into the T-2000 software to calculate, analyse and assess the collected data. Following mathematical analyses, the program can provide each athlete with the appropriate timeframes needed to successfully perform exercises into the zones: O2S (aerobic endurance), O2R (aerobic-anaerobic threshold), VO_2 max (aerobic power) and LT (lactate tolerance). T-2000 is a constant-pace triangular test (Marinescu, Ticală, Rădulescu, Bidiugan, & Petre, 2016). Athletes were split on a swimming line (eight lines) and tested at the same time.

5.4.2. Measured parameters

- swimming index: it was calculated by multiplying the swimming speed (m/s) by distance per stroke (m/cycle). This index assumes that, at a given speed, the athlete who swims with the highest DPS value has the most efficient swimming technique. This parameter was measured in the T-2000 test during the two test phases. During learning, improvement can be mainly achieved by using longer strokes, as a result of better orientation of motor surfaces (the swimmer's arms and legs that generate a propulsive force), and by

increasing the distances covered by motor surfaces. Moreover, the fastest swimmers have better swimming index, and therefore, better technique (Cardelli, Chollet, & Lerda, 1999);

- lactic acid (LA): this is a maximally important indicator for assessing the predominant type of energogenesis during physical exercise and, depending on the concentration reached, for assessing the endurance capacity of the body. The athlete's body develops lactate resistance during the effort, which is why their training sessions should include interval exercises that produce high increases in lactate concentration. The data were taken at the end of T-2000 test, during the first minute after exercise.

6. Findings

The results obtained in the initial and final tests are shown and analysed in Tables 01 and 02.

Table 01. Presentation and statistical analysis of the results obtained in the initial testing

Item no.	Full name (Initials)	Results			
		T-2000 test (seconds)	Average per 100m (seconds)	Swimming index	Post-exercise LA (mmol)
1.	A.B.	1457	72.85	2.5	11.96
2.	R.R.	1526	76.30	2.8	12.88
3.	K.L.	1500	75.00	1.9	10.24
4.	O.B.	1511	75.55	2.2	11.77
5.	S.D.	1550	77.50	2.3	11.47
6.	R.Z.	1552	77.60	2.9	13.95
7.	A.S.	1586	79.30	1.89	10.99
8.	H.M.	1528	76.40	2.7	14
9.	T.D.	1448	72.40	2.5	14.06
10.	F.H.	1502	75.10	2.1	11.7
11.	I.B.	1533	76.65	2.5	12.56
12.	M.M.	1556	77.80	2.2	12
13.	Z.J.	1616	80.80	2.6	13.16
14.	Z.B.	1451	72.55	2.6	12.98
15.	M.T.	1340	67.00	2.5	12.88
Statistical parameters					
minimum value		1340	67.00	1.89	10.24
maximum value		1616	80.80	2.9	14.06
average value		1510	75.52	2.4127	12.44
standard deviation		± 66.97	± 3.349	± 0.3056	± 1.129
coefficient of variation		4.43%	4.43%	12.66%	9.07%

Table 02. Presentation and statistical analysis of the results obtained in the final testing

Item no.	Full name (Initials)	Results			
		T-2000 test (seconds)	Average per 100m (seconds)	Swimming index	Post-exercise LA (mmol)
1.	A.B.	1452	72.60	2.6	11.8
2.	R.R.	1522	76.10	2.8	12
3.	K.L.	1495	74.75	2.2	10.2
4.	O.B.	1505	75.25	2.4	11.2
5.	S.D.	1542	77.10	2.4	11.4
6.	R.Z.	1542	77.10	2.9	12.5
7.	A.S.	1576	78.80	2.1	10.5
8.	H.M.	1518	75.90	2.9	12.2
9.	T.D.	1438	71.90	2.6	12.2
10.	F.H.	1502	75.10	2.3	11.2
11.	I.B.	1523	76.15	2.7	12.3
12.	M.M.	1546	77.30	2.5	11.69
13.	Z.J.	1606	80.30	2.8	12.9

14.	Z.B.	1441	72.05	2.7	12.2
15.	M.T.	1335	66.75	2.6	11.9
Statistical parameters					
minimum value		1335	66.75	2.1	10.2
maximum value		1606	80.30	2.9	12.9
average value		1503	75.14	2.567	11.75
standard deviation		± 65.89	± 3.294	± 0.247	± 0.736
coefficient of variation		4.38%	4.38%	9.61%	6.26%

Regarding the time achieved in the T-2000 test, its average is 25:10:00 minutes in the initial testing and 25:03:00 minutes in the final testing, the difference between the two tests being 07:00 seconds in favour of the second testing; the minimum value recorded within the group in the initial test is 22:20:00 minutes, and the maximum value is 26:56:00 minutes, the difference between these values being 04:36:00 minutes; in the final test, the minimum value is 22:15:00 minutes, and the maximum value is 26:46:00 minutes, the difference between these values being 04:31:00 minutes. Standard deviation in the initial test is equal to ± 01:06:97 minutes, and in the final test, it is equal to ± 01:05:89 minutes in favour of the second testing; the coefficient of variation in the initial test is 4.43%, and in the final test, it is 4.38%, which shows a high level of homogeneity of the results obtained in this test. Figure 01 graphically presents the differences between the values recorded in the two tests.

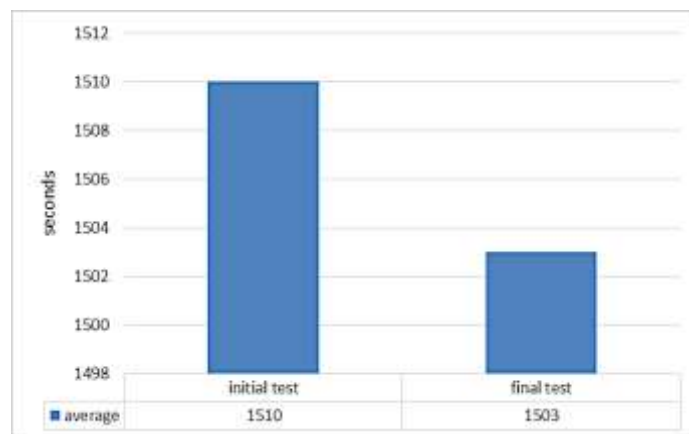


Figure 01. Average results obtained for the T-2000 test in the two testing phases

As for the average time per 100m within the T-2000 test, it is 01:15:52 minutes in the initial testing and 01:15:14 minutes in the final testing, the difference between the two tests being 00:38 seconds in favour of the second testing; the minimum value recorded within the group is 01:07:00 minutes in the initial test, and the maximum value is 01:20:80 minutes, the difference between these values being 13:80 seconds; in the final test, the minimum value is 01:06:75 minutes, and the maximum value is 01:20:30 minutes, the difference between these values being 13:55 seconds. Standard deviation in the initial test is equal to ± 03:34 seconds, and in the final test, it is equal to ± 03:29 seconds in favour of the second testing; the coefficient of variation in the initial test is 4.43%, and in the final test, it is 4.38%, which shows a high level of homogeneity of the results obtained in this test. Figure 02 graphically presents the differences between the values recorded in the two tests.

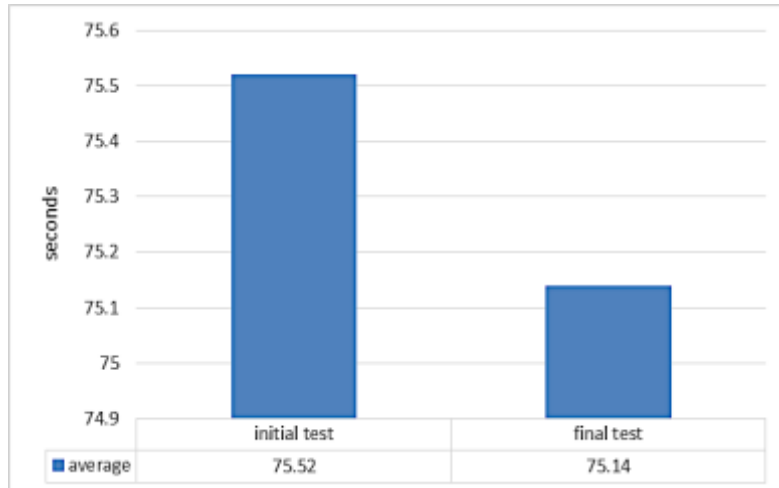


Figure 02. Average times per 100m for the T-2000 test in the two testing phases

Concerning the swimming index, its average is 2.412m/s in the initial test and 2.567m/s in the final test, the difference between the two tests being 0.155m/s in favour of the second testing; the minimum value recorded within the group in the initial test is 1.89m/s, and the maximum value is 2.9m/s, the difference between these values being 1.01m/s; in the final test, the minimum value is 2.1m/s, and the maximum value is 2.9m/s, the difference between these values being 0.8m/s. Standard deviation in the initial test is equal to ± 0.305 m/s, and in the final test, it is equal to ± 0.247 m/s in favour of the second testing; the coefficient of variation is 12.66% in the initial test, and in the final test, it is 9.61%, which shows a moderate level of homogeneity of the results obtained for this parameter. Figure 03 graphically presents the differences between the values recorded in the two tests.

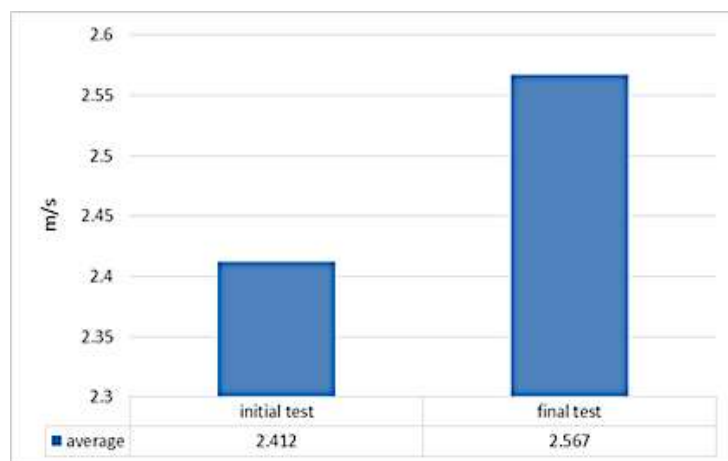


Figure 03. Results obtained for the swimming index parameter in the two tests

As regards the value of lactic acid accumulated in the blood at the end of the T-2000 test, its average is 12.44 mmol in the initial test and 11.75 mmol in the final test, the difference between the two tests being 0.69 mmol in favour of the second testing; the minimum value recorded within the group in the initial test is 10.24 mmol, and the maximum value is 14.06 mmol, the difference between these values being 3.82 mmol; in the final test, the minimum value is 10.2 mmol, and the maximum value is 12.9 mmol, the

difference between these values being 2.7 mmol. Standard deviation in the initial test is equal to ± 1.129 mmol, and in the final test, it is equal to ± 0.736 mmol in favour of the second testing; the coefficient of variation in the initial test is 9.07%, and in the final test, it is 6.26%, which shows a high level of homogeneity of the results obtained for this parameter. Figure 04 graphically presents the differences between the values recorded in the two tests.

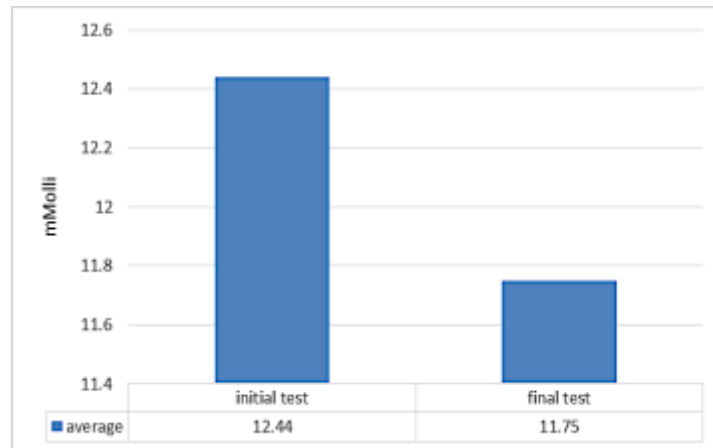


Figure 04. Results obtained for the LA parameter in the two tests

Tables 03 and 04 show the correlation between the post-exercise LA parameter (lactic acid value) and the swimming index parameter, a correlation achieved in the two tests. In the initial test, we notice a very strong positive association between the two parameters (LA and swimming index), the correlation coefficient being $r = 0.869$. Also, the r^2 value indicates that the dispersion of each of the two parameters is influenced by the other parameter in a proportion of 75.5%. In the final test, we notice a very strong positive association between the two parameters (LA and swimming index), the correlation coefficient being $r = 0.917$. Also, the r^2 value indicates that the dispersion of each of the two parameters is influenced by the other parameter in a proportion of 84%.

Table 03. The Pearson correlation coefficient and the determination coefficient between the two parameters in the initial testing

Post-exercise LA T1	Pearson correlation and Determination coefficient		Swimming index T1
	Correlation coefficient r		0.869
	Determination coefficient r^2		0.755
	N		15

Table 04. The Pearson correlation coefficient and the determination coefficient between the two parameters in the final testing

Post-exercise LA T2	Pearson correlation and Determination coefficient		Swimming index T2
	Correlation coefficient r		0.917
	Determination coefficient r^2		0.840
	N		15

7. Conclusion

High performance in world swimming depends on several factors: height of the athletes, the stroke rate and range of motion, coordination of the upper limbs, propulsive forces, accumulated lactic acid and ways of removing it, maximum heart rate etc., and there are many cases where, at a distance of a few hundredth of a second from the first time, an athlete is not on the podium or even in the final of the event.

Regarding our experiment, in the final test, an improvement in the studied parameters is noted for all parameters; average times for the T-2000 test are improved by 7 seconds, and there is only one case where the time achieved in the final test is identical to the time achieved in the initial test: the athlete F.H., with 25:02:00 minutes in both tests.

As for the average time per 100m in the T-2000 test, there is an improvement of 00:38 seconds, which, in our opinion, is significant, because it is about the training of high-performance athletes.

The swimming index has a moderate value in the initial test, 2.412m/s, and in the final test, 2.567m/s, the difference being 0.155m/s in favour of the second testing, which shows that the stroke efficiency has also improved due to the increase in the DPS parameter.

The post-exercise lactic acid parameter shows that the effort provided by athletes during the initial test falls within the metabolic zone of tolerance to lactic acid accumulation ($LA > 12$ mmol, $X = 12.44$ mmol), and in the final test, within the VO_2 max effort zone ($LA < 12$ mmol and $> 4-6$ mmol, $X = 11.75$ mmol). Thus, the research hypothesis that using short-term sprint exercises can lead to an increase in aerobic endurance (VO_2 max) is checked and confirmed.

Regarding the correlation between the two parameters, the swimming index and the value of post-exercise lactic acid, there is a very strong positive association between them: in the initial test, $r = 0.869$, and the determination coefficient r^2 shows that the dispersion of each of the two parameters is influenced by the other parameter in a proportion of 75.5%; in the final test, $r = 0.917$, and the determination coefficient r^2 shows that the dispersion of each of the two parameters is influenced by the other parameter in a proportion of 84%.

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