200M BREASTSTROKE POST-COMPETITION BLOOD LACTATE REMOVAL CHARACTERISTICS: A CASE STUDY OF AN INTERNATIONAL FEMALE SWIMMER—AN EXAMPLE OF INDIVIDUAL MODELING IN RELATION TO POOL LENGTH

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Abstract:

The goal of this study was to define the individual model characteristics of lactic acid removal after 200m breaststroke competitive load in a female swimmer in relation to different pool lengths (25m vs. 50m). The second goal was methodological and referred to the presentation of newly applied metrological procedures for the Individual Lactate Recovery Profile modeling. Six races from the competitive season 2021/22 were selected, in which the athlete achieved the most valuable results in relation to the FINA score. To establish the metabolic response of the organism to the competition effort, the method of determining the level of lactate concentration in capillary blood (La in mmol/L) was used. Differences between the mean values of variables were established using ANOVA. The polynomial curve equation function was used to create a blood lactate concentration in a function of recovery time model (La-$t_{recovery}$). The ANOVA showed that there was no statistically significant difference between the monitored variables and the pool length function (p=.097). The maximum achieved blood lactate concentration in the acute race recovery phase was 13.17 ± 2.81 and 12.08 ± 1.80 mmol/L and the given concentration initially occurred in the time of 240.0 ± 85.6 s and 169.3 ± 79.9 s in the 25 and 50m pool, respectively. In relation to the time of complete passive recovery required to establish acidosis at the level of 2 mmol/L (25 and 50m pool) occurred in 1191.7 ± 481.3 s and 1326.7 ± 405.1 s, while the full index of intensity of blood lactate clearance was 135.7 ± 60.7 s/mmol/L and 124.0 ± 60.7 s/mmol/L for 25m and 50m pool, respectively, although no statistically significant difference was found between the parameters of recovery in relation to pool length. The offered mathematical models enabled a practical individual approach to controlling the specific adaptation to training for achieving a higher competitive level performance.

Key words: *swimming, adaptation, modeling, training control*

Introduction

In competitive swimming, especially when elite athletes are regarded, lactate tests are usually used not only to describe the level of current adaptation of athletes' metabolic performance, but also to define appropriate goals, intensity, and volume of training (Olbrecht, 2011). Considering the physiology of sports training and metabolic reactions of the body to training and competitive effort, lactate acid is one of the most studied metabolites in sports science (Åstrand, Rodahl, Dahl, & Stromme, 2003; Bishop & Martino, 1993; Bonifazi, Sardella, & Lupo, 2000; Bosquet, Léger, & Legros, 2001; Kachunov, 2018; Keskinen, Keskinen, & Mero, 2007). This is especially common in relation to cyclic-type of sports, such as swimming, running, cycling, triathlon, Nordic skiing, etc., where the intensity of physical exertion can be estimated via the blood lactate concentration (Baron, et al., 2008; Beneke, Leithäuser, & Ochentel, 2011; Greenwood, Moses, Bernardino, Gaesser, & Weltman, 2008; Menzies, et al., 2010). New field-testing equipment for determining the blood lactate concentration, due to a high reliability of the device in combination with improved standards of measurement procedures, has provided better objectivity and validity of assessing the training intensity by means of determining blood lactate concentrations of swimmers, and athletes overall (Hart, Drevets, Alford, Salacinski, & Hunt, 2013; Pelayo, Mujika, Sidney, & Chatard, 1996).

The system of swimming competitions is such that swimmers often participate in preliminary, semi-final and final races, or swim several different races per day, that is, the current competition format results in multiple races in one day. This may require swimmers to exert multiple maximal specific competition effort several times, i.e., to swim multiple races in a short period of time (Greenwood, et al., 2008). In this sense, the adaptive ability of optimal fast recovery is of crucial importance because it enables the swimmer to repeat high-competitive performance on daily bases. The preparation of swimmers (a traditional or an alternative concept, as well as the characteristics and types of the preparatory cycle) and the application of training strategies also depend on the mentioned number of daily races in the competition and on the individual swimmer's characteristics of recovery after the race. In other words, the training should be designed in a way to improve the swimmer's individual recovery profile by stimulating optimal specific adaptation to it (Issurin, 2016; Šiljeg, Sindik, & Leko, 2017).

Establishing a system for collecting information on the status of blood lactate concentration after typical workloads is important for optimizing training intensity in order to improve training efficiency and recovery monitoring practice (Pollock, et al., 2019). In this way, conditions will be provided for improving the metabolic adaptation of swimmers, which can have a direct positive effect on competitive performance (Dopsaj, Di Nino, Thanopoulos, & Kežman, 2018; Pyne, Lee, & Swanwick, 2001).

In the current practice of sports training of top-level swimmers, the method of measuring the concentration of lactic acid in the blood is commonly applied to achieve the following: to determine optimal work intensity in the process of aerobic and anaerobic capacity development (Costa, et al., 2013); in the process of training control, as a measure of metabolic load for all intensity zones (Anderson, Hopkins, Roberts, & Pyne, 2006; Dopsaj, et al., 2018; Pelayo, et al., 1996); as a control of training efficiency, for planning the next training cycles, and as a measure of the athlete's cumulative adaptation to the previously realized training cycles (Hooper, Mackinnon, & Ginn, 1998; Pyne, et al., 2001) at all stages of the competition (Greenwood, et al., 2008; Vescovi, Falenchuk, & Wells, 2011), as well as in the prevention of acute and chronic overtraining (Beneke, et al., 2011; Bosquet, et al., 2001; Pelayo, et al., 1996). An appropriate system of control of blood lactate concentration levels is, therefore, an important methodological procedure in assessing recovery after maximum loads, regardless of whether it is training, testing or competition (Beneke, et al., 2011; Dopsaj, et al., 2018; Greenwood, et al., 2008; Vescovi, et al., 2011).

It is a well-known fact that athletes generally adapt differently to the training process (Olbrecht, 2011). The given diversity is primarily caused by the individual metabolic characteristics of the person's body, but it also depends on the event and swimming styles (Gonjo & Olstad, 2021; Šiljeg, et al., 2017). Due to the mentioned diversity phenomenon, the characteristics of swimmers' recovery after acute maximal competitive load are also individually different (Greenwood, et al., 2008; Pelayo, et al., 1996; Pyne, et al., 2001; Vescovi, et al., 2011).

However, from the aspect of scientific methodology, the phenomenon of recovery has been examined only from the aspect of achieved metabolic acidosis of swimmers after the race and, in the context of the type of swim-out protocol, with the aim to define recovery efficiency (Greenwood, et al., 2008; Menzies, et al., 2010). The limited research in this area of swimming has tended to focus on passive out-of-water vs. active recovery by swimming and has found the active recovery to be better at reducing after-race metabolic acidosis (blood lactate) than the passive one (Lomax, 2012). Unfortunately, no fully methodological procedure or metrological standards have been established yet for complete structural analysis of the profile of blood lactate clearance as an acute recovery profile after a specific swimming competitive load. Developing the methodology of the procedure aiming at defining standardized scientific-applied-metrological data processing can provide new knowledge useful in sports science, in general, or it can provide specific procedures in terms of improving the technology of sports training in swimming (Maglischo, 2003; Šiljeg, et al., 2017). Also, knowledge and understanding of the results obtained by measuring the level of blood lactate concentration in relation to the dynamics of its change in the recovery after maximum competitive loads will provide conditions for individualized implementation or correction of training work, which will enable a more effective process of training individualization and optimization as a current approach to the technology of training work with top-level athletes (Anderson, et al., 2006; Bonifazi, et al., 2000; Carrard, Kloucek, & Gojanovic, 2020; Costa, et al., 2013; Gulbin, Croser, Morley, & Weissensteiner, 2013; Lomax, 2012; Šiljeg, et al., 2017).

The primary goal of this study was to define the individual lactate recovery profile (ILRP), i.e., individual model characteristics of blood lactate removal after competitive load of the best Croatian 200m female breaststroke swimmer in relation to different dimensions of the pool (25m vs. 50m pool). The secondary goal of the study was predominantly methodological and referred to the presentation of newly applied metrological procedures for the ILRP modeling.

Methods

The main method used in this research was the *ex-post-facto* method, while the field-testing method was used to collect experimental data (Ribeiro, et al., 2020). By nature, this research belongs to the applied ones, and was realized in accordance with the conditions of the Helsinki Declaration for Recommendations Guided by Physicians in Biomedical Research Involving Humans (http://www.cirp.org/library/etike /helsinki/).

Sample of variables

The following nine variables were used in the study:

1. La_Peak, a hypothetical equivalent of blood lactate concentration at the end of the race, or mathematically calculated lactate concentration in the first second after the race, expressed in mmol/L;
2. La_Max, a hypothetical equivalent of maximum blood lactate concentration in the passive recovery after a race, defined by mathematical modeling, expressed in mmol/L;
3. La_Max_time_1, the time point of recovery at which the hypothetical equivalent of the period with the maximum concentration of blood lactate begins after the race (La_Max), defined in seconds (s);
4. La_Max_time_2, the time point of recovery at which the hypothetical equivalent of the period with the maximum concentration of blood lactate ends after the race (La_Max), defined in seconds (s);
5. La_Max$_{StedyState}$, time period of the maximum lactate concentration (La_Max) as a measure of the metabolic balance between the blood lactate production and blood lactate removal after the race, expressed in seconds (s);
6. La_Production_Int, a measure of the intensity of the lactate increment in the blood in the time interval from the end of the race to the beginning of La_Max_time_1, expressed in s/mmol/L;
7. La_Clearance_Int, a measure of the intensity of lactate removal from the blood in the time interval from the end of La_Max_time_2 to complete metabolic rest, i.e., to a lactate concentration of 2 mmol/L, expressed in s/mmol/L;
8. Full_rest_time_La2, the time interval of passive rest from the end of the race to complete metabolic recovery of the swimmer until the lactate concentration of 2 mmol/L, expressed in seconds (s);
9. Full_La_Clearance_Int, a measure of the intensity of full lactate removal from the blood in the time interval from the end of the race to complete metabolic rest, i.e., to a lactate concentration of 2 mmol/L, expressed in sec/mmol/L.

The sample of races and procedure for measuring blood lactate concentration

From the total sample of races swam in two consecutive competition seasons (2021 and 2022), six races were selected in which the monitored athlete achieved the most valuable results in relation to the FINA score (https://www.swimrankings.net). All races were swum in official competitions of FINA (World) and LEN (European Swimming Organization) in 25- and 50-meter pools (three for each pool length).

To measure the metabolic response of the organism to a specific competitive effort, the method of determining the level of lactate concentration in capillary blood (La in mmol/L) was used as a measure of acute metabolic acidosis (Bishop & Martino, 1993). For this purpose, in addition to sampling capillary blood, the exact time from the end of the race to each individual blood sample taken was measured. According to the applied procedure, the lactate concentration was measured from a sample of 0.2 μl of capillary blood taken from the finger at five time points of recovery: 3-, 5-, 7-, 10- and 15-minutes after the race (Dopsaj, et al., 2018). A Lactate Scout sensor blood lancet was used for blood sampling and lactate concentration was analyzed using a new generation portable lactate analyzer Lactate Scout 4 (EKF, Germany) (https://www.ekfdiagnostics.com/lactate-scout.html).

Statistical methods

All raw data were processed by descriptive statistical analysis for calculating basic statistical measures of central tendency (MEAN), absolute and relative dispersion of data – standard deviation (SD), coefficient of variation (%cV), and standard error of measurement (SEM) expressed in absolute and relative values. Differences between the mean values of the observed variables were established using the univariate analyses of variance (one-way ANOVA) with *post-hoc* multiple comparisons for the observed means of different swimming pool length post-race lactate recovery variables with corrections by Bonferroni criteria. The mathematical modeling method of applying the polynomial curve equation function was used to create an optimized individual model of the relation between the blood lactate concentration in the function of recovery time (absolute values: La-t$_{recovery}$, and relative values: %La-%t$_{recovery}$) (Dopsaj, et al., 2018; Pajić, Simović & Dopsaj, 2021). The statistical significance level was determined at the level of 95% of probability at the criterion of $p \leq .05$, while the IBM SPSS v23.0. software program was used for all statistical analyses (Hair, Anderson, Tatham, & Black, 1998).

Results

Table 1 shows the results of descriptive statistics as well as the differences between the analyzed variables of blood lactate concentration during recovery after swimming in different pools (25m and 50m). The ANOVA showed that there was no partial statistically significant difference between the monitored lactate recovery variables in the function of the pool length.

Based on the results (Table 1), the analyzed female swimmer's 200m breaststroke race in the 25m pool on average ended at the level of a metabolic acidosis of La_Peak = 10.95 ± 0.55 mmol/L, where the average race result was 808.7 ± 12.6 FINA points, i. e., with an average result of 2:24.43 ± 0:01.17 min:sec:hundred (swimming speed of 1.385 ± 0.007 m/s).

Considering the 50m-pool post-race recovery metabolic characteristics (Table 1), the analyzed swimmer on average ended a 200m breaststroke race at the metabolic acidosis of La_Peak = 11.62 ± 2.79 mmol/L, where the average race result was at 767.0 ± 19.3 FINA points, i.e., with an average result of 2:31.95 ± 0:01.27 min:sec:hundred (swimming speed of 1.316 ± 0.011 m/s).

The average value of the 25m-pool maximum blood lactate concentration (La_Max) after the race, in the acute recovery phase, was 13.17 ± 2.81 mmol/L and the given concentration occurred after the time span of 4:00.0 ± 1:25.6 and ended in 5:39.0 ± 1:44.5, i.e., the maximum lactate steady state lasted 1:39.0 ± 0:33.9 (min:sec:hundred, respectively) (Table 1).

After the 50m-pool race, the average value of the maximum blood lactate concentration (La_Max) in the acute recovery phase was 12.08 ± 1.80 mmol/L and this concentration occurred in 2:49.3 ± 1:19.9 after the race and ended in 5:11.3 ± 0:51.9, i.e. the, maximum lactate steady state lasted 2:22.0 ± 0:30.3 (min:sec:hundred,respectively) (Table 1).

In relation to the 25m-pool race, it was established that the average value of the index of intensity of blood lactate production (La_Production_Int) was 247.9 ± 135.0 s/mmol/L (production of 1 mmol/L lactate in the function of time, i.e., per 4:07.9 ± 2:15.0 min:sec:hundred), while the lactate removal on average occurred at an intensity of 78.7 ± 60.7 s/mmol/L (removal of the concentration of 1 mmol/L lactate as the function of time, i.e., per 1:18.7 ± 1:00.7 min:sec:hundred), i.e., from the La_max until the level of 2 mmol/L as the selected reference point of full metabolic rest. Considering the 50m-pool race, La_Production_Int was 288.3 ± 158.8, while lactate removal occurred on average with an intensity of 75.8 ± 12.1 s/mmol/L, respectively.

In relation to the time of complete passive recovery required to restore acidosis of 2 mmol/L, it was determined that it was at the level of 19:51.7 ± 8:01.3 and 22:06.7 ± 6:45.1 (min:sec:hundred), while the full index of intensity of blood lactate clearance (Full_La_Clearance_Int) was 135.7 ± 60.7 s/mmol/L (2:15.7 ± 1:00.7 min:sec:hundred) and 124.0 ± 60.7 s/mmol/L (2:04.0 ± 1:00.7 min:sec:hundred) for 25m and 50m pool (Table 1), respectively.

Figure 1 shows the defined models of blood lactate concentration-recovery rate (La-t$_{recovery}$) for the female swimmer A.B., and for the analyzed 200m breaststroke races in the 25m and 50m pools in 2021 and 2022 competition seasons considering absolute results. For the 25m pool, the obtained model of the polynomial model equation has the following form:

$$y = (-0.000013 \cdot X^2) + (0.004990 \cdot X) + 11.624929 \quad (1)$$

where y is blood lactate concentration, expressed in mmol/L, and X is time in post-race rest, expressed in seconds.

Table 1. Descriptive statistics in the function of determining recovery characteristics

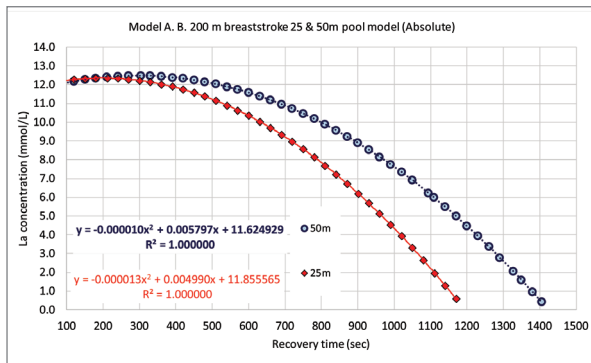| Pool	25m pool				50m pool				ANOVA	
Variables	MEAN±SD	cV%	SEM (Abs.)	SEM (Rel.)	MEAN±SD	cV%	SEM (Abs.)	SEM (Rel.)	F	p
FINA_points	808.7±12.6	1.6	7.3	0.9	767.0±19.3	2.5	11.1	1.4	9.820	0.035
La_Peak (mmol/L)	10.95±0.55	5.0	0.32	2.9	11.62±2.79	24.0	1.61	13.9	0.172	0.700
La_Max (mmol/L)	13.17±2.81	21.3	1.62	12.3	12.08±1.80	14.9	1.04	8.6	0.036	0.858
La_Max_time_1 (sec)	240.0±85.6	35.7	64.9	27.0	169.3±79.9	47.2	52.9	31.2	0.131	0.735
La_Max_time_2 (sec)	339.0±104.5	30.8	75.8	22.4	311.3±51.9	16.7	47.7	15.3	0.020	0.895
La_Max$_{SteadyState}$ (sec)	99.0±33.9	34.2	19.6	19.8	142.0±30.3	21.3	17.5	12.3	2.685	0.177
La_Production_Int (sec/mmol/L)	247.9±135.0	54.5	77.9	31.4	288.3±158.8	55.1	91.7	31.8	0.078	0.793
La_Clearance_Int (sec/mmol/L)	78.7±60.7	77.1	17.0	21.6	75.8±12.1	16.0	7.0	9.2	0.113	0.754
Full_rest_time_La2 (sec)	1191.7±481.3	40.4	277.9	23.3	1326.7±405.1	30.5	68.3	5.1	0.025	0.882
Full_La_Clearance_Int (sec/mmol/L)	135.7±60.7	44.7	35.1	25.9	124.0±41.3	33.3	23.8	19.2	0.075	0.797

Figure 1. Defined models of the blood lactate concentration-recovery rate (La-$t_{recovery}$) dependence on the pool length (absolute values) for the swimmer A.B.
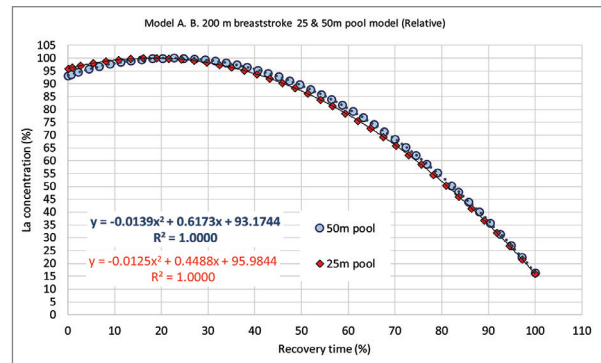

Figure 2. Defined models of the blood lactate concentration-recovery rate (La-$t_{recovery}$) dependence on the pool length (relative values) for the swimmer A.B.

The equation 1 had a high statistically significant power of explaining the variance (100.0%; R^2 = 1.000, p=.000).

For the 50m pool, the obtained model of the polynomial equation has the following form:

$$y = (-0.000010 \cdot X^2) + (0.005797 \cdot X) + 11.624929 \qquad (2)$$

where y is blood lactate concentration, expressed in mmol/L, and X is time in post-race rest, expressed in seconds.

The equation 2 also had a high statistically significant level of explaining the variance at 100.0% (R^2 =1.0000, p=.000).

Figure 2 shows the defined models of blood lactate concentration-recovery rate (La-$t_{recovery}$) for the analyzed swimmer A.B. in relation to the relativized curve values [La (%) – $t_{recovery}$ (%)], both expressed in %. For the 25m pool, the polynomial model equation has the following form:

$$y = (-0.0125 \cdot X^2) + (0.4488 \cdot X) + 95.9844 \qquad (3)$$

where y is post-race lactate concentration expressed in %, and X is time in post-race recovery expressed in %, and with a high statistically significant level of explaining the variance at 100.0% (R^2 = 1.0000, p=.000).

For the 50m pool, the polynomial equation model has the following form:

$$y = (-0.0139 \cdot X^2) + (0.6173 \cdot X) + 93.1744 \qquad (4)$$

where y is post-race lactate concentration expressed in %, and X is time in post-race recovery expressed in %, and also with a high statistically significant level of explaining the variance at 100.00% (R^2 =1.0000, p=.000).

In relation to the defined model of relative values of La (%)-$t_{recovery}$ (%) (Figure 2), it was found that the swimmer in the analyzed seasons finished races on metabolic acidosis at 93.17 and 95.98% of La_Max, and that the value of maximum metabolic acidosis La_Max reached 22.8 %, or 19.1% of

the time required for complete metabolic recovery down to 2 mmol/L, for 50m and 25m pool, respectively. Half (50.0% of La_Max) of metabolic acid recovery was achieved in the time interval of 82.4% (1094 s or 17:54.0), or 81.2% (902 s or 15:02.0).

Discussion and conclusions

The results shown in the research belong to the metrological presentation of applied statistical and mathematical methods in determining the dependence of blood lactate concentration and recovery rates in individual absolute and relative model for swimmer A.B. in relation to the analyzed 200m breaststroke races in the 25m and 50m pools for the 2021/2022 competition season. Although no statistically significant difference was found between the analyzed metabolic variables, descriptive as well as model characteristics were determined for the purpose of an individual approach to training efficiency control and metabolic adaptation for the monitored athlete.

Based on the results (Table 1) it can be concluded that the analyzed female swimmer's 200m breaststroke race in the 25m and 50m pool on average ended at the level of a metabolic acidosis of La_Peak = 10.95 ± 0.55 mmol/L and 11.62 ± 2.79 mmol/L, respectively.

The average value of the 25 and 50m-pool maximum blood lactate concentration (La_Max) after the race, in the acute recovery phase, was 13.17 ± 2.81 mmol/L and 12.08 ± 1.80 mmol/L, respectively (Table 1).

The measured maximum blood lactate concentrations are in line with the previously published studies for 200m breaststroke female senior swimmers because they are in the range between 11.0 and 13.0 mml/L, which was determined for Canadian swimmers (Vescovi, et al., 2011), almost the same as for the Bulgarian swimmers (12.89±2.29; Kachunov, 2018), which proves the external validity of the current results. Also, the results of the present study confirmed a previously established fact that,

after races in the Olympic pool (50m) compared to races in short pools, swimmers have higher metabolic lactate acidosis by about 14.9% (Lowensteyn, Perry, Nash, & Salhanick, 1994), or 6.12%, as shown by the results of our study.

Based on the results shown in Table 1, it can be concluded that the highest level of coefficient variation (cV%) but also relative measurement errors (SEM rel) have the variables La_Clearance_Int 25m pool and La_Production_Int 50m pool (54.5 and 31.4%, and 55.1 and 31.8 %, respectively), which is certainly an indication that the given variables can be sensitive markers of the acute state of adaptation of athletes. In relation to the time of complete passive recovery required to restore acidosis of 2 mmol / L, it was determined that it was at the level of 1191.7 ± 481.3 ($19:51.7 \pm 8:01.3$ min:sec:hundred) and 1326.7 ± 405.1 seconds ($22:06.7 \pm 6:45.1$ min:sec:hundred), while the full index of intensity of blood lactate clearance (Full_La_Clearance_Int) was 135.7 ± 60.7 sec/mmol/L ($2:15.7 \pm 1:00.7$ min:sec:hundred) and 124.0 ± 60.7 sec/mmol/L ($2:04.0 \pm 1:00.7$ min:sec:hundred) for 25m and 50m pool (Table 1), respectively.

Pelayo and co-workers (1996) found that the intensity of lactate removal from the blood can be an efficient marker for monitoring the impact of aerobic and anaerobic training for the purpose of avoiding overtraining in elite 200m swimmers. Also, Greenwood and co-workers (2008) concluded that in after-race situations swimmers must have more than 10 minutes to recover. They found that 10 minutes of passive recovery reduced blood lactate from 9.2 to 7.1 mmol/L, which only suggests that a considerable recovery time would be required for the restoration of baseline blood lactate values. In our research, we found that for complete recovery (down to acidosis of 2 mmol/L) with a passive approach the examined athlete needed from 1191.7 ± 481.3 to 1326.7 ± 405.1 seconds (19:51.7 till 22:06.7 min:sec:hundred), for the 25m and 50m pool, respectively.

In the only study available, in which there was some quantification of post-race lactate clearance, the authors found that the given ability was at the level of 0.18 ± 0.17 for passive and 0.43 ± 0.17 mmol L/min for active recovery after swimming the 200m crawl (Rabelo Mota, et al., 2017). However, as they used a completely different method of calculating the given recovery variables, comparing their results with the current ones is not possible.

The ANOVA results showed that no statistically significant difference was found between the monitored metabolic recovery variables as the function of pool length at the partial level (Table 1, from La_MaxSteadyState - F = 2.685, p=.177, to La_Max_time_2 - F = 0.020, p=.895). The only difference was found between the levels of FINA points (Table 1; 808.7 vs. 767.0 points; the difference of 5.43%, F = 9.820, p=.035), which was expected because

swimmers on average have better results in 25m compared to 50m pools by about 4.5% (Keskinen, et al., 2007).

In relation to the defined model of relative values of La (%)-$t_{recovery}$ (%) (Figure 2), it was found that the swimmer in the analyzed seasons finished races on metabolic acidosis at 93.17 and 95.98% of La_Max, and that the value of maximum metabolic acidosis - La_Max reached 22.8 %, or 19.1% of the time required for complete metabolic recovery down to 2 mmol/L, for 50m and 25m pool, respectively. Half (50.0% of La_Max) of metabolic acid recovery was achieved in the time interval of 82.4% (1094 s or 17:54.0), or 81.2% (902 s or 15:02.0).

High homogeneity of competitive performance (FINA_Score, 1.6 vs. 2.5%, Table 1) and analyzed metabolic parameters of recovery (La_Peak and La_Max, from 5.0 until 24.0%), and low homogeneity in other variables of time parameters (La_Max_time_1, La_Max_time_2, La_Max$_{SteadySate}$, La_Production_Int, La_Clearance_Int, Full_rest_time_La2, and Full_La_Cearance_Int) can be explained by the fact that the athlete is in the category of swimmers with a competitive achievement of about 800 FINA_points, which denotes top-level swimmers (swimmers competing at a European and World Championships). In other words, in relation to achieved swimming results, a small variation in competitive performance indicates highly developed and stable physiological, physical, technical, tactical and competitive performance abilities of the observed swimmer.

The athlete was followed over a period of the annual macrocycle (March 2021—March 2022), where she completed different phases of preparation, i.e., she participated in races at different preparatory stages (Bonifazi, et al., 2000). In other words, the athlete participated in the competitions while being in different states of cumulative fatigue, i.e., in heterogeneous states of adaptation to different types of training, which means in different phases of fatigue and rest as different functional parts of the training annual cycle (Hooper et al., 1998; Pelayo, et al., 1996).

Comparing the intensity of blood lactate increase with the intensity of blood lactate decrease, it can be stated that A.B. should also work on the development of aerobic capacity, i.e., on faster removal of blood lactate in order to be ready for the next race as soon as possible and in order to maintain the efficiency of swimming to the last meter. The offered mathematical models enable a practical individual approach as a function of specific adaptation control of the effects of training for the purpose of achieving a higher competitive performance expressed in FINA points.

Finally, the obtained results, as the function of the innovative metrological procedure of monitoring the given phenomenon, important in the

control system of training efficiency and the level of adaptation achieved by top-level swimmers, have a scientific and comparative practical value. The development of analytical methods in the function of improving sports scientific methodology for the purposes of achieving top sports results in swimming is one of the bases of the progress of the high-performance training system.

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