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An Analysis of Blood Lactate Responses on Land and Water Active Recovery after Maximum Sprint Swimming

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Abstract

Purpose: Achieving top performance requires recovery to be at its best. Lactic acid is one of the main byproducts of anaerobic activity, and its buildup has a detrimental impact on the player's performance. In this case, the optimum strategy for lactate clearance is active recovery. Furthermore, swimmers benefit most from self-paced active recuperation. But now the issue was: Should swimmers favour self-paced land recovery or water recovery? This study has been undertaken to comprehend the analysis of Blood Lactate Responses on Land and Water Active Recovery after Maximum Sprint Swimming. **Methods:** Ten male competitive swimmers at the national level from the Rewa District in Madhya Pradesh (Age: 23.6 ± 3.2 years; Height: 1.74 ± .05 m; Weight: 68.30 ± 8.76 kg; BMI: 22.68 ± 2.90 k g/m²) were selected as subjects. Subjects performed a 200-meter individual medley with their best effort and then underwent a 20-minute active recovery. Subjects were separated evenly into two groups for post-workout recovery: recovery on land (LR) and recovery in water (WR), and measurements of blood lactate, heart rate, and respiratory rate were recorded. **Results:** Descriptive statistics and a 2-way mixed ANOVA at the level of significance of 0.05 were used to analyze the data. The findings indicated that the 200m IM can elevate heart and breathing rates to peak values. The data revealed that the land recovery (7.88 + 0.70852) and water recovery (3.74 + 0.80187) significantly removed lactate after 20 minutes of self-paced active recovery. This study revealed a significant difference between pre-warm-up lactate reading and post-200m IM ($p = 0.000$) and post-200m IM and post 20 min active recovery ($p = 0.000$). Further, comparing lactate clearance rates in land recovery and water recovery, it was found that water recovery clears lactate significantly higher ($P = 0.014$).

Key Words: Active land recovery, Active water recovery, Blood lactate, Swimming performance.

INTRODUCTION

Recovery after exercise or competition is a crucial part of the exercise training paradigm and necessary for peak performance and ongoing development (Hinzpeter et al., 2014a; McMaster et al., 1989a). Higher training volumes and intensities are feasible without suffering the negative consequences of overtraining if the recovery rate is appropriate. For individuals who compete in swimming or track events, where they might be required to put out two or more all-out efforts in a short period, quick recovery is exceptionally crucial (Maglischo, c2003; Toubekis et al., 2008; Westerblad & Allen, 2003)

An increase in the concentration of H+ ions inside our bodies is the leading cause of weariness. The body becomes more acidic (pH decreases) due to the increase in H+ ions, and because pyruvic acid accepts H+ ions, they are converted to lactic acid (Hinzpeter et al., 2014b; Martin et al., n.d.). The oxyhemoglobin dissociation curve (ODC), caused by the body's acidity, moves to the right, and the Bohr effect occurs inside the body. As a result, hemoglobin and other molecules have lower affinities. Because of the loss in affinity, oxygen and other molecules cannot move from one location to another as desired. This disrupts the process of generating energy during exercise, causing the person to feel exhausted and unable to continue their activity with the present amount of energy (Bogdanis et al., 1995; Sesboüé & Guincestre, 2006; Toubekis et al., 2008). Notably, the most significant buildup of H+ is observed during high-intensity activity lasting 1 to 10 minutes (Cairns, 2006), characteristic of sprint and middle-distance swimming time frames (Maglischo,1993). As a result, research on swimming has concentrated on the post-exercise decrease in blood lactate concentration as a measure of recovery (Cazorla et al., n.d.; McMaster et al., 1989a; Toubekis et al., 2008).

Active recovery (low-intensity swimming) and passive land recovery have frequently been compared in previous swimming studies, with active recovery being found to lower blood lactate more effectively than passive land recovery (Franchini et al., n.d.; Greenwood et al., 2008; Neric et al., 2009; Toubekis et al., 2005; Toubekis et al., 2005; Toubekis et al., 2006; A. Toubekis et al., 2008). With an increase in exercise intensity, lactatemia showed a gradual rise. In a study with activity, both groups saw a rise of 4.6 mmol/L or a 78% increase in lactate. In the recovery phase, the active exercise recovery group saw a mean drop in lactate concentration of 5.93 mmol/L, or 68% of the original total. In contrast, the group that rested experienced a decrease in lactate concentration of 1.63 mmol/L, or 20% of the initial total (Hinzpeter et al., 2014b).

Self-paced Active Recovery (swim down or sometimes land exercises) exhibits a faster blood lactate elimination rate than Passive Recovery. These findings imply that athletes might be able to select their optimal recovery intensity (Mota et al., 2017). Athletes typically warm down with brief, intermittent exercise after a match or training session. When light, continuous activity is undertaken during recovery following the strenuous exercise, lactic acid clearance from muscle and blood is quick. Swimmers usually felt most at ease at around 65% of their maximum speed, providing a valuable reference point for the athlete (McMaster et al., 1989b).

Free-jogging recovery eliminates lactic acid more quickly than free-intermittent and resting processes (Bonen & Belcastro, 1976). For instance, the first 10 minutes of continuous light jogging eliminate 62% of the

lactic acid, while the following 10 minutes remove an additional 26%. Implementing an active recovery time of 10 to 20 minutes following lactic training sessions is therefore desirable (Bonen et al., 1979). During competitive practice, some elite British swimmers prefer to do land exercises instead of swimming down. For instance, perform short swim downs or skip rope leaps, then conduct land exercises or get a massage (Vorontsov & Phillips, 2015). However, not every competition is hosted in a venue with a swim-down pool. Light-intensity walking, skipping, and stretching are typically done on the ground as an altar-native method of aiding blood lactate elimination (Lomax, 2012). On the contrary, according to the research by Welford et al. and McCurdy, swimmers recover more quickly in the water than on the pool deck after a strenuous swim.

Numerous studies also preferred active recovery in the case of lactic acid elimination in swimming. However, this idea is not entirely obvious when discussing the degree, length, and surface of recovery. No technique has been sufficiently demonstrated through controlled study to provide a more effective recovery, even though numerous have been attempted and are now being utilized worldwide (Frost, Reuben B., 1975). Ferreira et al. also suggested comparing active recovery on land to active recovery in water (Ferreira et al., 2011). Therefore, the researchers decided to study this area to determine which surface is best for recovery at the same intensity as on land and in water.

PURPOSE OF THE STUDY/EXPERIMENTAL APPROACH

Blood lactate is a by-product of high-intensity exercise and is linked to lower performance (Smith et al., 2002). To lower blood lactate concentration (LAC), many athletes include a warm-down phase in their training or after competition. The majority of previous swimming studies have compared active water recovery (low-intensity swimming) to passive land recovery, concluding that active recovery lowers blood lactate more effectively than passive land recovery (Lomax, 2012). But this area has been untouched with active recovery on different surfaces. Hence, researchers have reviewed the problem to compare which surface would be better for swimmers for quick lactic acid removal. As a result, the researchers investigated the blood lactate responses in swimmers during active recovery on land and water following maximal sprint swimming.

HYPOTHESIS

It was hypothesized that swimmers' blood lactate responses would significantly differ between active land recovery and active water recovery following maximal sprint swimming.

METHODOLOGY

SUBJECTS

Ten male national-level competitive swimmers (Age: 23.6 ± 3.2 years; Height: 1.74 ± .05 m; Weight: 68.30 ± 8.76 kg; BMI: 22.68 ± 2.90 k g/m²) who can perform individual medley in competition in under 193.7 ± 12.5 s were selected from Rewa District, Madhya Pradesh, India. All the selected subjects were medically fit and had at least five years of competitive experience.

EXPRIMENTAL PROCEDURE

The subjects were instructed about the whole schedule for mental preparation. Each swimmer was asked about their medical history and to disclose any other conditions limiting their ability to exercise long-term or temporarily. The subjects were divided into The land recovery group (LR) and the water recovery group (WR). To warm up the body, the swimmers of both groups, at the same time, swam continuously for 200 meters at their self-selected pace. Swimmers could choose the number of laps to warm up properly, and the researchers were allowed to do so. Post warm-up, the 200 IM test started as an official swimming competition, and all the swimmers gave their best timing. In the post-200 IM, the swimmers were engaged in active recovery at their self-selected pace within 10 seconds for 20 minutes, according to the land recovery or water recovery groups (Cazorla, G., n.d.). The water recovery group swam inside the pool at a self-selected pace (freestyle and front crawl), while the land recovery group jogged constantly on the pool deck.

The subjects' first blood Lactate value (LAC1) was taken just before the 200IM. Post 200IM intervals of two minutes, for the second time, the blood lactate value (LAC_2) was collected (Mavroudi et al., 2023). This reading revealed the participants' peak lactate levels. The third and final reading of lactate value (LAC_3) was recorded after 20 minutes of land and water recovery. Only 0.5 µL of a capillary blood sample from the fingertip was taken, and a POC lactate device (Lacto spark; Sensa core maker, EPIP Zone, Pashamylaram, Sangareddy (Dist.), Hyderabad, India) was used to measure the blood lactate values.

First heart rate (HR1) and breathing rate (BR1) readings were collected before warming up. The second reading of heart rate (HR_2) and breathing rate (BR_2) were recorded just before the 200 IM. Immediately after the 200IM, the participants were permitted to recline on the pool deck, and their third heart rate (HR_3) and breathing rate (BR_3) readings were recorded as promptly as possible. The pulse oximeter (Dr. Trust USA Pulse Oximeter 213; 2765th Avenue, Suite 704-397, New York-10001, USA) was used to measure heart rate and breathing rate (Alwadhi et al., 2020)

The experiment was conducted in a 50-meter open swimming pool with the following environmental conditions: 30.3 °C in ambient air, 27.67 °C in the water, 12.1 km/h wind, 54.0% humidity, and 1004.0 hPa of atmospheric pressure.

STATISTICAL ANALYSIS

The Statistical Package for Social Sciences (SPSS) software 20 for Windows was used to evaluate the data and determine the estimated values. 2-way ANOVA was used to determine whether self-paced active recovery on land and water following maximal sprint swimming can significantly decrease the lactic acid concentration (Greenwood et al., 2008) (Table 3). Before employing the 2-way ANOVA, the normal distribution of the data was tested using the Shapiro–Wilk test. Levene's test of error variances was employed to determine the homogeneity of variance of the data. For all statistical tests, the level of significance to test the hypothesis was set at $p = 0.05$, which was considered sufficient. For easy comparison of mean differences, line diagrams were incorporated.

FINDINGS OF THE STUDY

Table 1 Tests of Normality

Group		Shapiro-Wilk		
		Statistic	Df	Sig.
LAC1	WR	.909	5	.464
	LR	.920	5	.528
LAC2	WR	.964	5	.832
	LR	.962	5	.823
LAC3	WR	.986	5	.965
	LR	.994	5	.992

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Table 1 illustrated that the LAC data at the three levels (LAC1, LAC2, and LAC3) for both WR and LR groups are normally distributed ($p > 0.05$).

Table 2 Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
LAC1	3.177	1	8	.113
LAC2	3.633	1	8	.093
LAC3	.077	1	8	.789

Since the p-values (LAC1 = .113, LAC2 = .093, LAC3 = .789) of Levene's test of equality of error variances for the Lactic acid responses (LAC) of two groups (WR and LR) at the three different levels showed higher than the significance value of 0.05, so equal variance is accepted.

Table 2 Descriptive statistics of heart rate and breathing rate

	N	Minimum	Maximum	Mean	Std. Deviation
HR1	10	70	80	75.00	5.270
RR1	10	16	21	18.90	1.663
HR2	10	90	135	117.20	12.541
RR2	10	22	38	31.10	4.458
HR3	10	170	220	188.00	14.944
RR3	10	35	56	46.50	7.352

HR1: Pre-warm-up heart rate **RR1:** Pre-warm-up breathing rate **HR2:** Post warm-up heart rate **RR2:** Post warm-up breathing rate **HR3:** Post 200m IM heart rate **RR3:** P Post 200m IM breathing rate

Table 2 shows the descriptive statistics of heart rate (HR) in 3 different situations, i.e., before warm-up (HR1 = 75.00 $\pm$ 5.270), after warm-up (HR2 = 117.20 $\pm$ 12.541) and after 200m IM (HR3 = 188.00 $\pm$ 14.944). Similarly, the reading of the respiratory rate (RR) at three levels. Pre-warm-up (RR1 = 18.90 $\pm$ 1.663); post-warm-up (RR2 = 31.10 $\pm$ 4.458) and post 200m IM (RR3 = 46.50 $\pm$ 7.352).

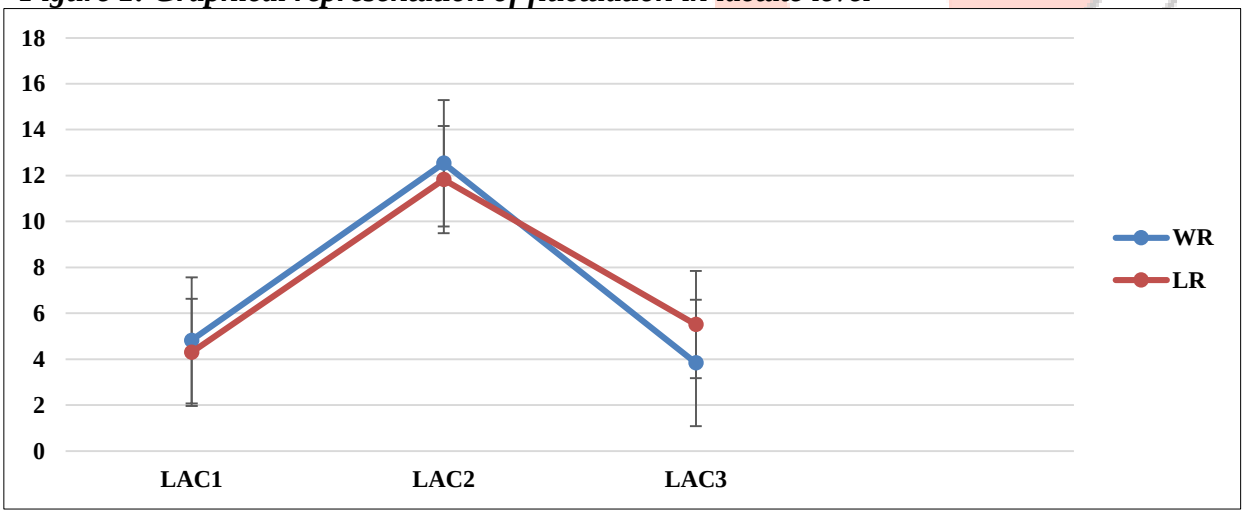
Blood Lactate Concentration:

Table 3 Descriptive statistics of Blood lactate responses in various conditions

RECOVERY SURFACE		LAC1	LAC2	LAC3
WR	Mean	4.8200	12.5400	3.8400
	N	5	5	5
	Std. Deviation	.78867	.86776	.50794
LR	Mean	4.3000	11.1200	7.1800
	N	5	5	5
	Std. Deviation	1.60935	.28636	.48166
Total	Mean	4.5600	11.8300	5.5100
	N	10	10	10
	Std. Deviation	1.22583	.96500	1.82114

The descriptive statistic of Table 3 revealed that the average post warm-up lactic acid accumulation value (LAC1) was 4.30 ± 1.60935 in the land recovery group (LR), 4.82 ± 0.78867 in the water recovery group (WR), further the average post 200m IM lactic acid accumulation value (LAC2) in swimmers body was found to be 11.12 ± 0.28636 in land recovery group (LR) and 12.54 ± 0.86776 in water recovery (WR) group, finally after the self -paced active recovery the average lactic acid value (LAC3) was 7.18 ± .48166 in the land recovery group and 3.84 ± .50794 in the water recovery group.

Figure 1: Graphical representation of fluctuation in lactate level



Blood Lactate Concentration values during Post warm-up (LAC1), Post 200m IM (LAC2), and Post 20 minutes Active Water Recovery Group (WR) and Active Land Recovery Group (LR) (N=10, Mean + SD).

Table 4 Pairwise comparisons

(I) LAC	(J) LAC	Mean Difference (I-J)	Std. Error	Sig. [b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-7.270*	.481	.000	-8.719	-5.821
	3	-.950	.350	.080	-2.006	.106
2	1	7.270*	.481	.000	5.821	8.719
	3	6.320*	.276	.000	5.488	7.152
3	1	.950	.350	.080	-.106	2.006
	2	-6.320*	.276	.000	-7.152	-5.488

*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Concerning the blood lactate acid responses, Table 4 indicated that there were significant differences between post warm up lactate value (1) and post-200 m IM lactate value (2) ($p = .00 < .05$) and similarly significant difference between post 200IM blood lactate value (2) and post 20 min recovery blood lactate value (3) ($p = .00 < .05$). But there was no difference between post warm-up lactate value (1) and post 20 min recovery lactate value (3) ($p = .00 < .08$). It referred that the self-paced active recovery may lower the blood lactate concentrations even after 200 m IM sprint in swimming.

Table 5 Pairwise Comparisons

(I) RECOVERY SURFACE	(J) RECOVERY SURFACE	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
WR	**LR**	-.960*	.237	.004	-1.507	-.413
LR	**WR**	.960*	.237	.004	.413	1.507

*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

To test the research question of whether there was any difference between water and land recovery relating to a decrease in the blood lactate value, two-way repeated measures were applied. The comparisons between active water recovery (WR) and active land recovery (LR) (Table 5) revealed that there was a significant difference between the surfaces ($p = .004 < 0.05$) while concerning the effective blood lactic acid decrement after maximal sprint in swimming.

DISCUSSION OF FINDINGS

The primary goal of the study was to compare land recovery (LR) with water recovery (WR) in self-paced active recovery after maximal sprint swimming. It's significant to note that high-intensity activity lasting between one and ten minutes, which is typical of the time frame for sprint and middle-distance swimming, results in the most significant buildup of H+ in the body (Maglischo,1993; Cairns, 2006). The lactic acid concentration, heart

rate, and respiratory rate were all observed to increase quickly as exercise intensity increased at post warm-up and post 200 IM of the subjects in this study (Table 2). Previous research found a significant link between heart rate, respiratory rate, and body temperature when used in the activity zone (McLaren et al., 2018). The results of this investigation reinforced the idea that swimmers executed the 200m IM at high effort, with anaerobic respiration dominating, and that a boost in lactate level (LAC1 = 4.56 ± 1.23; LAC2 = 11.83 ± .97) increased considerably.

The result of the study indicated that active recovery in both cases (land recovery and water recovery) significantly helped to lower blood lactate from the body (Table 4). It has already been proved in previous studies that active recovery allows a very high rate of lactate clearance from the body after a high-intensity workout (Menzies et al., 2010). Since muscles continually create lactic acid, it is present in the blood even while the body is at rest. The equilibrium between supplying lactic acid to the blood and eliminating lactate from the circulation by muscle and the heart for metabolic processes governs blood lactate concentration and fluctuations. Lactate clearance may be facilitated by increased blood flow through lactate-using organs such as the liver and heart. According to a previous study, the faster distribution of lactate to the liver for oxidation or conversion to glycogen, the increased use of lactate by the heart muscle, and a potential increase in the oxidation of lactate used as fuel for muscle work all contribute to the increased rate of lactate removal during recovery exercises (Belcastro & Bonen,1975; Gisolfi et al.,1966). As a result, active recovery for 20 -30 minutes after exerting maximum effort helps to reduce oxygen debt and lower blood lactate levels.

Regarding the optimal zone of active recovery, self-paced active recovery is the greatest for lactic acid clearance (Bonen & Belcastro,1976). As it relates to the responses of blood lactate acid, Table 4 demonstrated that there were significant differences between the post-warm-up lactate value (1) and the post-200 IM lactate value (2) ($p = .00 < .05$), as well as a comparable significant difference between the post-200 IM blood lactate value (2) and the post-20 min recovery lactate value (3) ($p = .00 < .05$). However, there was no significant difference between the post-warm-up lactate value (1) and the post-20-minute recovery lactate value (3) ($p = .00 < .08$). It indicated that even after a 200-meter individual medley sprint in swimming, self-paced active recovery might reduce blood lactate concentrations.

It is evident from the study findings that self-paced active recovery in water is a better mode for swimmers post-maximal swimming. It is visible from the values of Table 5 that water recovery is more efficient in removing lactate compared to land recovery ($p = .004 < .05$). The descriptive statistic of Table 3 also revealed that the mean of the post-20 minutes self-paced active recovery blood lactate value (LAC3) in water recovery group (WR) was 3.8400 ± .50794, whereas in that condition the blood lactate value in land recovery group (LR) was found 7.18 ± .48166. It showed that self-paced active recovery in water was somehow more effective than that of land recovery.

The data said that the lactate level of land recovery (LR) swimmers did not feel as much as the lactate level of the water recovery (WR) swimmers' fells. This may be because swimmers were adapted to the buoyant environment. In contrast, when they worked against gravity, i.e., on land, physiologically and psychologically, they felt stress to do work and they did not feel comfortable (at 30.3 °C in ambient air). The environmental

temperature may also affect physiological responses (Heart rate, Breathing rate, and Blood Lactate Concentration). Results from past studies show that a hot, dry atmosphere may cause blood lactate concentration to rise higher and LT and OBLA to shift to the left (Shou & Ishiko,1994). A previous study showed that physiological responses were affected in cold or hot conditions compared to moderate temperatures. The blood lactate concentration during submaximal activity was considerably lower at 22 ± 1 ℃ than it was at 10 ± 1 ℃ and 35 ± 1 ℃ at 5 minutes and 10 minutes, respectively (No & Kwak, 2016). Hence, the blood lactate concentration of the land recovery swimmers may be found to be high as compared to the water recovery swimmers. However, the outcomes of earlier research employing 15–20 minute recovery times represent that a land-based recovery would eliminate more incredible amounts of lactate than a passive recovery (Neric et al., 2009); A. Toubekis et al., 2008).

The therapeutic benefits of water and the physiological changes that follow from immersion in a liquid medium have been extensively explored. The metabolism of waste built up during exercise may be aided by increased blood flow underwater (Wilcock et al., 2006). Furthermore, as the venous return is enhanced in such circumstances, more blood-carrying lactate could reach the visceral area, which is considered a significant location of lactate elimination (Stamford et al., 1978). Due to the advantages of hydrostatic compression when immersed, it is preferable to carry out recovery measures in a pool rather than on dry land. The alterations in blood flow brought on by the fluid shifts will improve the ability to eliminate blood lactate (Belcastro & Bonen, 1975; Buchheit et al., 2010).

CONCLUSION AND RECOMMENDATIONS

It was concluded that self-paced active water recovery must be preferred compared to self-paced active land recovery by the swimmers for quick lactate clearance. Following the conclusion of this investigation, the researchers recommended future research possibilities to achieve significant advancement in understanding the impact of surfaces in the clearance of lactic acid from the body and the reasons why these possible benefits may be associated with an increase in performance. Coaches may utilize a more organized method for post-competition recovery now that low-cost, practical, portable lactate testing is available. A fast lactate profile should allow each athlete to recover at their lactate threshold, aiding post-race recovery. The present study can be repeated with female swimmers, junior age group swimmers, or adult swimmers. The same study can be done on different race swimmers or with swimmers of different states. Further study on the complete lactate clearance period can be done on swimmers. This type of study can also be done on other games where the players need quick recovery between consecutive events.

References:

1. Alwadhi, V., Sarin, E., Kumar, P., Saboth, P., Khera, A., Gupta, S., & Kumar, H. (2020). Measuring the accuracy of plethysmography based respiratory rate measurement using pulse oximeter at a tertiary hospital in India. *Pneumonia*, *12*(1), 4. https://doi.org/10.1186/s41479-020-00067-2

2. Belcastro, A. N., & Bonen, A. (1975). Lactic acid removal rates during controlled and uncontrolled recovery exercise. *Journal of Applied Physiology*, *39*(6), 932–936. https://doi.org/10.1152/jappl.1975.39.6.932

3. Cairns, S. P. (2006). Lactic Acid and Exercise Performance: Culprit or Friend? *Sports Medicine*, *36*(4), 279–291. https://doi.org/10.2165/00007256-200636040-00001

4. Ferreira, J., Da Silva Carvalho, R., Barroso, T., Szmuchrowski, L., & Śledziewski, D. (2011). Effect of Different Types of Recovery on Blood Lactate Removal After Maximum Exercise. *PJST*, *18*(2), 105–111. https://doi.org/10.2478/v10197-011-0008-4

5. Frost, Reuben B. (1975). *Physical Education: Foundations, Practices, Principles*. Addison-Wesley Publishing Company.

6. Gisolfi, C., Robinson, S., & Turrell, E. S. (1966). Effects of aerobic work performed during recovery from exhausting work. *Journal of Applied Physiology*, *21*(6), 1767–1772. https://doi.org/10.1152/jappl.1966.21.6. 1767

7. Greenwood, J. D., Moses, G. E., Bernardino, F. M., Gaesser, G. A., & Weltman, A. (2008). Intensity of exercise recovery, blood lactate disappearance, and subsequent swimming performance. *Journal of Sports Sciences*, *26*(1), 29–34. https://doi.org/10.1080/02640410701287263

8. Lomax, M. (2012). The Effect of Three Recovery Protocols on Blood Lactate Clearance After Race-Paced Swimming. *Journal of Strength and Conditioning Research*, *26*(10), 2771–2776. https://doi.org/10.1519/JSC.0b013e318241ded7

9. Maglischo, E. W. (1993). *Swimming even faster*. Mayfield Pub.

10. Mavroudi, M., Kabasakalis, A., Petridou, A., & Mougios, V. (2023). Blood Lactate and Maximal Lactate Accumulation Rate at Three Sprint Swimming Distances in Highly Trained and Elite Swimmers. *Sports*, *11*(4), 87. https://doi.org/10.3390/sports11040087

11. McLaren, S. J., Macpherson, T. W., Coutts, A. J., Hurst, C., Spears, I. R., & Weston, M. (2018). The Relationships Between Internal and External Measures of Training Load and Intensity in Team Sports: A Meta-Analysis. *Sports Medicine*, *48*(3), 641–658. https://doi.org/10.1007/s40279-017-0830-z

12. Menzies, P., Menzies, C., McIntyre, L., Paterson, P., Wilson, J., & Kemi, O. J. (2010). Blood lactate clearance during active recovery after an intense running bout depends on the intensity of the active recovery. *Journal of Sports Sciences*, *28*(9), 975–982. https://doi.org/10.1080/02640414.2010.481721

13. Montpetit, R. R., & Cazorla, G. (n.d.). The Influence of Active Recovery on Blood Lactate Disappearance after Supramaximal Swimming. *Biomechanics and Medicine in Swimming (1983)*, 244–250.

14. Neric, F. B., Beam, W. C., Brown, L. E., & Wiersma, L. D. (2009). Comparison of Swim Recovery and Muscle Stimulation on Lactate Removal After Sprint Swimming. *Journal of Strength and Conditioning Research*, *23*(9), 2560–2567. https://doi.org/10.1519/JSC.0b013e3181bc1b7a

15. No, M., & Kwak, H.-B. (2016). Effects of environmental temperature on physiological responses during submaximal and maximal exercises in soccer players. *Integrative Medicine Research*, *5*(3), 216–222. https://doi.org/10.1016/j.imr.2016.06.002

16. Shou, G.-C., & Ishiko, T. (1994). The Effect of Different Environmental Conditions on Blood Lactate Accumulation, Lt And Obla During Incremental Exercise. *Japanese Journal of Physical Fitness and Sports Medicine*, *43*(1), 58–65. https://doi.org/10.7600/jspfsm1949.43.58

17. Toubekis, A. G., Douda, H. T., & Tokmakidis, S. P. (2005). Influence of different rest intervals during active or passive recovery on repeated sprint swimming performance. *European Journal of Applied Physiology*, *93*(5–6), 694–700. https://doi.org/10.1007/s00421-004-1244-9

18. Toubekis, A. G., Smilios, I., Bogdanis, G. C., Mavridis, G., & Tokmakidis, S. P. (2006). Effect of different intensities of active recovery on sprint swimming performance. *Applied Physiology, Nutrition, and Metabolism*, *31*(6), 709–716. https://doi.org/10.1139/h06-075

19. Toubekis, A., Tsolaki, A., Smilios, I., Douda, H., Thomas, K., & Tokmakidis, S. (2008). Swimming Performance After Passive and Active Recovery of Various Durations. *International Journal of Sports Physiology and Performance*, *3*, 375–386. https://doi.org/10.1123/ijspp.3.3.375