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ORIGINAL ARTICLE

Physiology of Responses to Active and Passive Recovery Strategies After Maximal Exercise: A Study in Track and Field Athletes

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

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ABSTRACTS

Purpose	The accumulation of lactic acid in muscle cells during intense exercise can decrease muscle and blood pH, leading to weakened muscle contractions and fatigue. The purpose of this study was to determine the effect of active recovery (jogging) on reducing blood lactate levels after a 400-meter sprint in male college students.
Materials and Methods	An experimental study with a randomized control group and a pretest-posttest design was used. Twenty subjects were randomly divided into two groups of 10: a treatment group with active recovery (jogging) and a control group with passive recovery (sitting). Lactate levels were measured twice: after running and after a 5-minute recovery period. Data analysis used in this study included descriptive tests, normality tests, paired-samples t-tests, and independent-samples t-tests.
Result	The research results show that active recovery significantly reduces lactate levels from an average of 16.88±3.28 mMol/L to 9.97±1.28 mMol/L, whereas passive recovery reduces them only from 16.55±2.37 mMol/L to 15.63±2.08 mMol/L. The paired t-test results showed a significant difference ($p < 0.05$) between the two recovery methods.
Conclusion	These findings indicate that active recovery is more effective in accelerating the reduction of lactic acid levels, reducing the risk of muscle fatigue, and enhancing athletes' readiness for subsequent training or competitions.
Keywords	Lactic acid; Active recovery; Passive recovery; 400-meter run.

INTRODUCTION

Athletics is a physical activity that requires optimal physical and mental readiness. One of the most physically and physiologically demanding events in athletics is the 400-meter sprint (Cicchella, 2022). The 400-meter sprint is classified as a short-distance run, but its intensity is very high, causing the body to expend energy more quickly than in other sports (Hasegawa et al., 2024).

According to Duffield et al. (2005), the predominant energy systems in the 400-meter run are 12% phosphagen, 50% glycolytic, and 38% oxidative. Based on these predominant energy systems, the 400-meter run predominantly utilizes the anaerobic glycolytic energy system. The glycolytic system is a type of energy metabolism that produces lactic acid as a byproduct. The

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accumulation of lactic acid in the body is often associated with fatigue, muscle soreness, and reduced physical performance, especially after intense physical activity such as the 400-meter sprint (Theofilidis et al., 2018; Zhao et al., 2023).

The accumulation of lactic acid can lead to persistent fatigue, which hinders an athlete's recovery (Cairns & Lindinger, 2025b). Therefore, as an athlete who regularly engages in intense training, implementing recovery strategies is crucial to maintaining optimal performance in both training and competition. One effective recovery method for reducing lactic acid levels is active recovery. Engaging in light physical activity after intense exercise can accelerate the process of eliminating lactic acid from the body (Katoch et al., 2025). Recovery is a crucial aspect of sports, as it impacts fitness, performance, and an athlete's ability to perform and avoid injury consistently (Li et al., 2024). Obstacles to this recovery process are crucial issues that require special attention. One of the main issues faced by the UNESA Athletics Student Activity Unit (UKM) is the lack of active recovery methods and the limited availability of adequate recovery facilities.

This condition results in increased fatigue and longer recovery times, which can ultimately affect performance in training and competition. Blood lactate is a biomarker that can assess muscle acidity and monitor exercise, routines, or athletic performance (Huang et al., 2025). In research by Fajar et al. (2024) and Kojima et al. (2025), blood lactate concentration after physical exercise was used to determine the success of post-exercise recovery strategies. Recovery active jogging is one of the most common forms of active recovery used by athletes. According to O'Connor et al. (2022), jogging during the recovery period increases blood flow to working muscles, improving oxygen delivery to tissues and accelerating the removal of lactic acid and other metabolic byproducts. Low-intensity jogging (<65% HRmax) after physical activity that utilizes the lactate energy system requires a minimum of 3 minutes of rest, followed by 5 minutes of light exercise. Lactic acid accumulation decreases by up to 62% in the first 10 minutes and increases by 26% in the next 10-20 minutes, demonstrating its effectiveness in reducing blood lactate levels and improving muscle function (Ortiz et al., 2019).

This research data is expected to contribute to the field of sports science by determining the effect of active recovery jogging on blood lactic acid levels after a 400-meter sprint. By understanding the mechanisms of muscle fatigue caused by lactic acid accumulation and examining the effects of active recovery methods, this research is expected to provide practical solutions that improve athletes' daily performance, particularly in the 400-meter sprint event. This study is not only relevant for UKM athletes but also has the potential to provide broader benefits for national sports development.

METHODS

Study Participants

This study was a quasi-experimental group study with a randomized control group pretest-posttest design. Twenty active college students, aged 18-21, participated in the study. Inclusion criteria included college athletes in the 100m, 200m, and 400m events, training three times per week, and not experiencing any injuries in the past two months.

Blood Samples

Blood samples were drawn to evaluate pre- and post-workout lactate levels using an Accutrend Plus meter. Pre-workout lactate levels were measured immediately after exercise, and post-workout blood samples were drawn 5 minutes after active recovery. Heart rate was monitored

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during exercise and recovery using a Polar H10 for each athlete. A stopwatch was used for training management and time measurement.

Training Program

The training program consisted of athletes performing four repetitions of a 400-meter run at 90% of their maximum heart rate. A 3-minute rest period was provided between each training session, using active and passive recovery protocols. The entire 400-meter run training session was conducted on an internationally standardized field and monitored using the Polar Team app and a stopwatch. The recovery strategy protocol involved jogging on a running track, with heart rate continuously monitored at 65% of HRmax for 5 minutes via the Polar Team app. The control group performed passive recovery by sitting down immediately. Fluids were provided after all lactate measurements and heart rate monitoring were completed.

Statistical Analysis

The data analysis in this study included descriptive tests, normality tests, paired-samples t-tests, and independent-samples t-tests. SPSS 21 was used to assist researchers in data analysis.

RESULT

Table 1. Description of fatigue indicators in both groups

Group	Fatigue Indicator	n	Mean±SD	P-Value Normality	Sig. Paired test
Treatment	Lactate Pre	10	16.88±3.28	0.070*	0.001
	Lactate Post		9.97±1.28	0.311*	
	Delta Lactate			0.613*	
Control	Lactate Pre	10	16.55±2.37	0.983*	0.001
	Lactate Post		15.63±2.08	0.873*	
	Delta Lactate			0.011	
Treatment	HR Ex Pre	10	186.40±3.84	0.524*	0.001
	HR Ex Post		116.80±6.68	0.412*	
	Delta HR Ex			0.186*	
Control	HR Ex Pre	10	188.70±4.86	0.516*	0.001
	HR Ex Post		111.60±5.54	0.336*	
	Delta HR Ex			0.620*	

P>0.05; data are normally distributed; Paired Sample t-test Pre and Post for all groups are different.

Table 1 presents the fatigue indicators for both groups. All variables were normally distributed ($p > 0.05$), and paired-sample t-tests showed significant pre–post differences within each group. Overall, the active recovery group demonstrated a substantially greater reduction in blood lactate than the passive recovery group. In contrast, heart rate recovery declined similarly in both groups, with no meaningful difference in the magnitude of the change.

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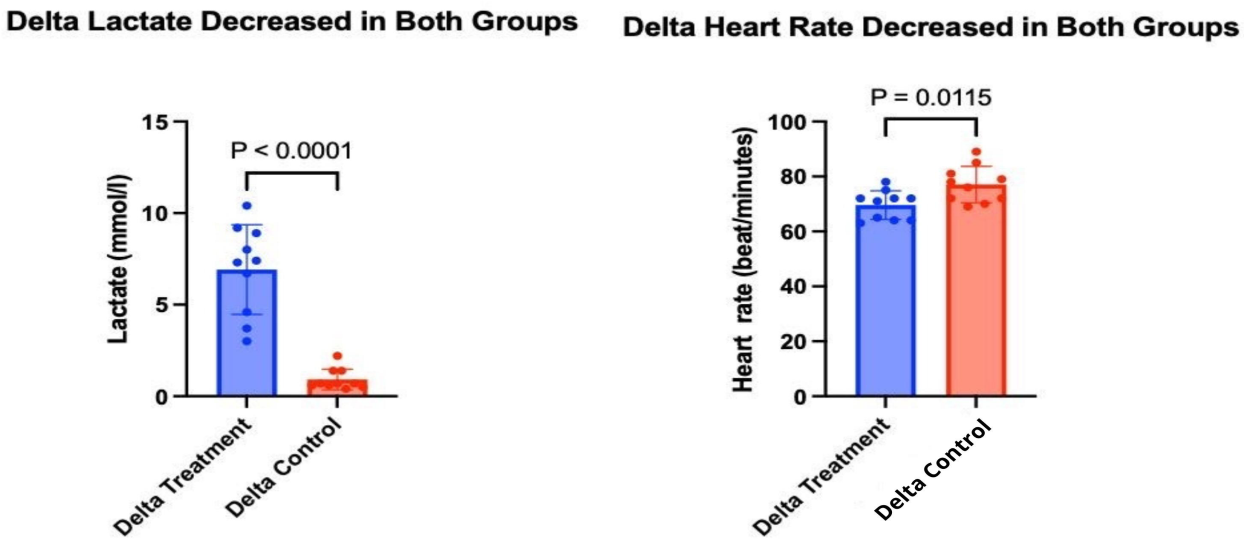

Figure 1. The Difference in the decrease in lactate and heart rate in both groups

Figure 1 illustrates the pattern of lactate and heart rate changes. The active recovery group showed a markedly greater decrease in lactate concentration, approximately a 40% reduction, whereas the passive recovery group exhibited only a minimal decline. Heart rate decreased in both groups following exercise, with a comparable magnitude of reduction.

DISCUSSION

This study provides evidence that active recovery significantly enhances lactate clearance compared to passive recovery. The more rapid decrease in blood lactate concentration observed in the active recovery group aligns with previous findings (Menzies et al., 2010; Özsu et al., 2018), which emphasized the role of sustained post-exercise muscle activity in promoting metabolic recovery.

From a physiological perspective, active recovery helps sustain venous return and oxygen delivery, enabling more efficient conversion of lactate to pyruvate through the lactate shuttle mechanism (Bartoloni et al., 2024; Brooks, 2018; Gladden, 2000). Pyruvate is subsequently oxidized in the mitochondria to regenerate ATP, allowing lactate to be used as a fuel rather than being accumulated (Cai et al., 2023; Rabinowitz & Enerbäck, 2020; Tauffenberger et al., 2019). This mechanism contributes to faster restoration of acid–base balance and reduced fatigue, which are critical during repeated high-intensity efforts (Gough et al., 2018; Liakou et al., 2024; Yamaguchi et al., 2020).

Active recovery also enhances oxygen availability, supporting lactate-to-pyruvate conversion via lactate dehydrogenase (Kumar et al., 2025; Wang & Zhu, 2025). Pyruvate then enters the mitochondria for oxidation in the citric acid cycle, contributing to ATP production (Bonora et al., 2012; Liu et al., 2025). Interestingly, active recovery can increase lactate uptake by muscles that are not physically active, facilitating its elimination into the bloodstream (Nalbandian et al., 2017). Organs such as the liver convert lactate to glucose via the Cori cycle, while the myocardium and oxidative fibres utilize lactate directly as an energy source (Bartoloni et al., 2024). Thus, through these various metabolic mechanisms, lactate clearance is accelerated, which, in turn, affects the rate of acid-base recovery and reduces post-exercise acidosis (Cairns & Lindinger, 2025). Active recovery may also influence lactate transport by increasing the activity of monocarboxylate

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transporters (MCT1 and MCT4), which facilitate lactate exchange across cell membranes. Regular active recovery could enhance long-term adaptations in lactate handling efficiency in trained athletes.

Interestingly, despite its metabolic benefits, active recovery does not produce a significant difference in heart rate recovery. The post-exercise decrease in heart rate is primarily regulated by parasympathetic reactivation, which begins rapidly after exercise stops (Stanley et al., 2013). Therefore, although jogging facilitates metabolic clearance, it may not substantially alter autonomic cardiac recovery compared to passive rest, especially over short recovery intervals. For athletes and coaches, implementing active recovery such as light jogging or cycling for 3–5 minutes between sprints or training intervals can effectively lower blood lactate levels, thereby facilitating better performance in subsequent efforts. However, heart rate recovery alone should not be used as the sole indicator of full physiological recovery.

Limitations of this study include a small sample size (n = 10 per group), a short recovery period, and a focus solely on acute effects. Future research should incorporate larger sample sizes, continuous monitoring of lactate kinetics, and more extended recovery periods to more comprehensively explore the interplay between metabolic and autonomic recovery.

CONCLUSION

This study shows that active recovery is more effective than passive recovery at accelerating lactate clearance after high-intensity exercise, underscoring the value of maintaining low-intensity activity to support metabolic recovery. Nevertheless, the small sample size (n = 10 per group) and short recovery duration limit the generalizability of the findings. Future studies with larger samples, more extended recovery periods, and alternative recovery strategies, such as contrast water therapy or active cycling, are recommended to confirm and expand upon these results.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest that could affect the results or process of this research.

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