Do aerobic and anaerobic exercises differently affect muscle and liver biomarkers in young adult males?

¿Afectan los ejercicios aeróbicos y anaeróbicos de manera diferente a los biomarcadores musculares y hepáticos en hombres adultos jóvenes?

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Abstract

Introduction: Exercise, despite its well-established benefits, can lead to several adverse effects, including muscle injuries and significant elevations in liver enzymes.
Objective: This study investigated the effects of aerobic and anaerobic exercise on serum biomarkers of muscle injury (lactate, LDH, CK) and liver function (ALT, AST).
Methodology: Eighteen healthy young male adults were randomized to a 4-week aerobic (n=9) or anaerobic (n=9) exercise program. Blood samples were collected pre- and post-intervention to measure the aforementioned biomarkers.
Results: Both aerobic (p=0.028) and anaerobic (p=0.027) exercise significantly increased LDH activity. Lactate levels did not significantly change in either group. CK activity significantly decreased after aerobic exercise (p=0.003) but not after anaerobic exercise (p=0.231). No significant changes in ALT or AST activity were observed in either group.
Discussion: The observed LDH increase aligns with existing literature, while the contrasting CK response (decrease after aerobic, no change after anaerobic exercise) highlights differing impacts on muscle integrity. Consistent with prior research, no significant changes in liver enzymes (ALT/AST) were observed, suggesting no exercise-induced liver stress.
Conclusions: These findings reveal distinct effects of aerobic and anaerobic exercise on muscle biomarkers, with only aerobic exercise significantly decreasing CK levels, while both affected LDH. Importantly, no evidence of exercise-induced liver stress was observed based on ALT/AST levels.

Keywords

Aerobic exercise; anaerobic exercise; muscle injury; liver function test; biomarkers.

Resumen

Introducción: El ejercicio, a pesar de sus beneficios bien establecidos, puede provocar varios efectos adversos, incluidas lesiones musculares y elevaciones significativas de las enzimas hepáticas.
Objetivo: Este estudio investigó los efectos del ejercicio aeróbico y anaeróbico sobre biomarcadores séricos de lesión muscular (lactato, LDH, CK) y función hepática (ALT, AST).
Metodologia: Dieciocho hombres adultos jóvenes sanos fueron asignados aleatoriamente a un programa de ejercicio aeróbico (n=9) o anaeróbico (n=9) de 4 semanas. Se recolectaron muestras de sangre antes y después de la intervención para medir los biomarcadores mencionados.
Resultados: Tanto el ejercicio aeróbico (p=0,028) como el anaeróbico (p=0,027) aumentaron significativamente la LDH. El lactato no cambió significativamente. La CK disminuyó significativamente tras ejercicio aeróbico (p=0,003), pero no tras anaeróbico (p=0,231). No hubo cambios significativos en ALT/AST.
Discusión: El aumento observado de LDH concuerda con la literatura existente, mientras que la respuesta contrastante de CK (disminución tras ejercicio aeróbico, sin cambios tras ejercicio anaeróbico) destaca diferentes impactos sobre la integridad muscular. En consonancia con investigaciones previas, no se observaron cambios significativos en las enzimas hepáticas (ALT/AST), lo que sugiere la ausencia de estrés hepático inducido por el ejercicio.
Conclusiones: Estos hallazgos revelan efectos distintos del ejercicio aeróbico y anaeróbico sobre los biomarcadores musculares, y solo el ejercicio aeróbico disminuyó significativamente los niveles de CK, mientras que ambos afectaron la LDH. Es importante destacar que no se observó evidencia de estrés hepático inducido por el ejercicio según los niveles de ALT/AST.

Palabras clave

Ejercicio aeróbico; ejercicio anaeróbico; lesión muscular; prueba de función hepática; biomarcadores.

Introduction

Young adults' participation in sports and physical activity has increased significantly in recent years, reflecting a growing emphasis on healthy lifestyles (Centers for Disease Control and Prevention, 2023). This demographic is increasingly engaging in both aerobic exercises, such as running and cycling, and anaerobic exercises, including weightlifting and high-intensity interval training. While the benefits of regular physical activity, including improved cardiovascular health, mental well-being, and social skills, are well-documented, it is also essential to acknowledge the associated risks, particularly musculoskeletal injuries (Shigematsu et al., 2023). Studies have shown that exercise-related injuries are a significant concern, necessitating preventive measures and proper training to mitigate these risks. Therefore, it is crucial to emphasize the importance of understanding the balance between the benefits and potential hazards of physical activity. This understanding is key to promoting safe and sustainable exercise habits among young adults (Nunes et al., 2017; Hauret et al., 2010).

The mechanisms underlying muscle injuries differ between aerobic and anaerobic exercise (Chamari & Padulo, 2015). Long-term, moderate-intensity exercises like swimming and running are known as aerobic exercises because they mainly use oxygen to produce energy (Markov et al., 2022). This high oxygen consumption can lead to the overproduction of reactive oxygen species (ROS), harmful molecules generated when oxygen is not fully reduced, resulting in damaging free radicals (Markov et al., 2022; Lundberg et al., 2022; Uzawa et al., 2023). Anaerobic exercise, involving short bursts of high-intensity activity, can also elevate ROS levels through various mechanisms, including activating specific enzymes, altering blood flow, and disruptions in cellular processes (Markus et al., 2021). Through oxidative damage to cellular constituents such as lipids, proteins, and DNA, ROS plays a role in muscle injury during exercise. Although the body possesses antioxidant defenses to neutralize ROS, excessive ROS production during strenuous exercise can overwhelm these defenses, leading to oxidative stress (Markus et al., 2021). This oxidative stress can then compromise muscle cell membranes, impair protein function, and disrupt mitochondrial efficiency, contributing to muscle weakness and inflammation (Jabbour et al., 2015).

Recent research on muscle injury has focused on identifying biomarkers that can provide insights into the mechanisms and extent of damage (McGee & Hargreaves, 2020). For aerobic exercise, biomarkers such as serum lactate and interleukin-6 (IL-6) have been extensively studied (Nash et al., 2022; Hojman et al., 2019). In anaerobic exercise, creatine kinase (CK) and lactate dehydrogenase (LDH) are commonly used to assess muscle damage. Elevated CK levels following high-intensity resistance exercise suggest injury to the muscle cell membrane (Chaki et al., 2024; Barbosa et al., 2017). A recent case study reported exercise-induced increases in alanine aminotransferase (ALT) and aspartate transaminase (AST) more than double the normal values in a healthy adult male engaged in regular running and resistance exercise. This case raises the question of a potential link between exercise and changes in liver function (Tiller & Stringer, 2023). This potential link is further supported by research demonstrating the positive impact of various exercise modalities on liver health. A recent meta-analysis of studies examining the effects of physical exercise on liver function markers (AST, ALT, GGT, ferritin, indirect bilirubin, and ALP) concluded that resistance training, aerobic training, and high-intensity interval training (HIIT) interventions could favorably reduce these biochemical markers, with a meta-analysis specifically showing a reduction in ALT in exercise groups (dos Santos et al., 2023). While this research highlights the benefits of regular exercise for liver health, it also suggests a potential interplay between exercise intensity and liver function, warranting further investigation. Therefore, this study investigated the effects of both aerobic and anaerobic exercise on biomarkers of muscle injury (lactate, LDH, and CK) and liver function (ALT and AST). Advancements in biomarker research are crucial for developing targeted interventions to prevent and treat exercise-induced muscle injuries.

Method

This research was conducted in compliance with the Declaration of Helsinki and received ethical clearance from the Ethics Committee of the Faculty of Medicine, University of Indonesia – Cipto Mangunkusumo Hospital (approval number KET-1085/UN2.F1/ETIK/PPM.00.02/2024). The study utilized a true experimental design involving pre- and post-testing..

Participants

Eighteen healthy young adult male participants (Table 1) were enrolled in this study. All participants were non-smokers with no known medical conditions. Prior to enrollment, all participants received a detailed explanation of the study's purpose, benefits, and procedures and provided written informed consent. Participants were randomly assigned to one of two groups: an aerobic exercise group (n = 9) and an anaerobic exercise group (n = 9).

Table 1. Anthropometric data of research subjects

Variables	Mean ± SD
Age (years)	19.2 ± 0.6
Height (cm)	170.4 ± 4.8
Weight (kg)	59.4 ± 5.1
Body mass index	19.2 ± 2.8

Exercise protocol

Prior to the exercise program, all participants' blood pressure was measured. Participants with a systolic blood pressure ≥ 130 mmHg or a diastolic blood pressure ≥ 90 mmHg were excluded. Participants were required to have a maximum oxygen consumption (VO2max) greater than 40 mL/kg/min to be eligible for inclusion. Both groups then performed the exercise program as detailed in Table 2

Table 2. The exercise program

Phase	Aerobic exercise	Anaerobic exercise
Pre-exercise	All subjects underwent a test to determine their maximum running distance for 15 minutes.	All subjects underwent a test to determine their maximum running time by running 50 m, 100 m, and 150 m.
Pre-exercise blood sampling	Before starting the exercise program, 5 mL of blood was drawn from each subject to analyze ALT, AST, CK, LDH, and lactate levels.	
Exercise Week I	Run intervals of 2 sets of 10 repetitions of 400 meters each, with 3 minutes of rest between repetitions and 10 minutes of rest between sets.	Sprint intervals of 2 sets of 5 repetitions each, covering distances of 20 m, 40 m, 60 m, and 80 m, with 5 minutes of rest between repetitions and 10 minutes of rest between sets
Exercise Week II	Continuous running 15 – 20 minutes	Sprint intervals of 2 sets of 5 repetitions of 50 meters each, with 5 minutes of rest between repetitions and 10 minutes of rest between sets.
Exercise Week III	30 minutes cross country run	Sprint intervals of 2 sets of 5 repetitions each, covering distances of 20 m, 40 m, 60 m, and 80 m, with 5 minutes of rest between repetitions and 10 minutes of rest between sets.
Exercise Week IV	Run intervals of 2 sets of 10 repetitions of 400 meters each, with 3 minutes of rest between repetitions and 10 minutes of rest between sets.	Sprint intervals of 2 sets of 5 repetitions of 50 meters each, with 5 minutes of rest between repetitions and 10 minutes of rest between sets.
Post-exercise blood sampling	After completing the exercise program, 5 mL of blood was drawn from each subject for the analysis of ALT, AST, CK, LDH, and lactate levels.	

Measurement of ALT, AST, CK, LDH, and Lactate Levels

Blood samples were centrifuged at 3000 rpm for 15 minutes to obtain plasma. Plasma alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatine kinase (CK), lactate dehydrogenase (LDH), and lactate levels were measured using commercially available assay kits from Elabscience®. The following assay kits were used: ALT (E-BC-K235-M), AST (E-BC-K236-M), CK (E-BC-K558-S), LDH (E-BC-K046-M), and lactate (E-BC-K002-M). For all assays, plasma samples were analyzed according to the manufacturer's instructions. Briefly: 5 µL of plasma was used for ALT and lactate assays; 50 µL was used for the CK assay; and 20 µL was used for the LDH assay.

Statistical Analysis

Statistical analyses were performed using SPSS version 24 for Windows (IBM Corp., Armonk, NY). The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality of data distribution. Normally distributed data were analyzed using paired t-tests (for within-group comparisons) and unpaired t-tests (for between-group comparisons). Non-normally distributed data were analyzed using the Mann-Whitney U test. Data are presented as mean ± standard error of the mean (SEM). A p-value < 0.05 was considered statistically significant. Figures were generated using Microsoft Excel.

Results

This study measures serum levels of exercise-related muscle injury biomarkers—LDH, lactate, and CK—before and after four weeks of aerobic or anaerobic exercise. As shown in Table 3, serum LDH activity increases significantly after both aerobic (p = 0.028) and anaerobic (p = 0.027) exercise. Serum lactate levels, however, show no significant change for either exercise type. In contrast, CK activity decreases significantly after aerobic exercise (p = 0.003) but not after anaerobic exercise (p = 0.231). Furthermore, ALT and AST levels are measured to assess their role as supporting biomarkers of muscle damage and to evaluate the effect of exercise on liver function. These measurements reveal no significant changes in either ALT or AST levels before and after exercise, regardless of exercise type.

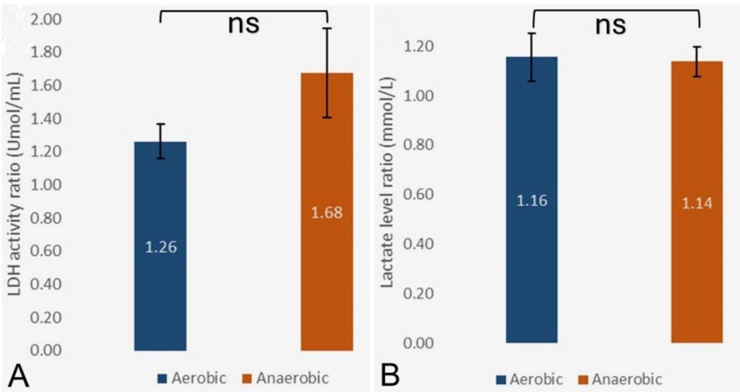
Table 3. Measurement results of muscle injury biomarkers before and after four weeks of aerobic and anaerobic exercise

Parameters	Aerobic		Anaerobic	
	Pre	Post	Pre	Post
LDH (Umol/mL) [a,b]	540.19 ± 22.358	677.88 ± 50.223	460.26 ± 52.038	677.39 ± 66.238
Lactate (mmol/L)	2.14 ± 0.127	2.40 ± 0.138	1.30 ± 0.099	1.46 ± 0.097
CK (U/L) [a]	8.55 ± 0.731	4.70 ± 0.616	7.55 ± 1.231	6.55 ± 0.967
ALT (U/L)	1.35 ± 0.262	3.273 ± 0.967	1.35 ± 0.233	2.02 ± 0.870
AST (U/L)	20.25 ± 2.142	23.48 ± 3.707	30.69 ± 11.906	19.10 ± 4.803

“a" and "b" represent the significant results of the paired t-test for aerobic and anaerobic exercise, respectively, at a p-value < 0.05.

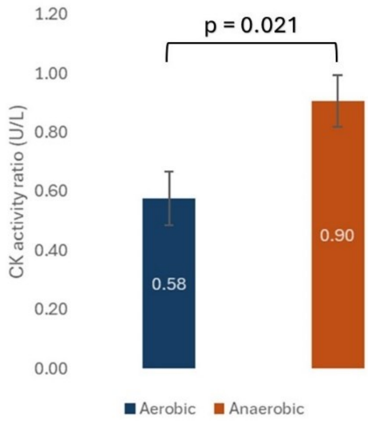
LDH and lactate are reliable biomarkers for monitoring muscle health and recovery in athletes and individuals engaging in intense physical activity. In this study, values are expressed as ratios to compare changes between the two groups before and after four weeks of exercise. The mean serum LDH activity ratio is lower in the aerobic group (1.26 ± 0.103 µmol/mL) compared to the anaerobic group (1.68 ± 0.271 µmol/mL); however, this difference is not statistically significant (t-test; p = 0.173). Similarly, the mean serum lactate level ratio shows no statistically significant difference between the groups (t-test; p = 0.877), with values of 1.16 ± 0.096 mmol/L and 1.14 ± 0.060 mmol/L for the aerobic and anaerobic groups, respectively (Figure 1).

Figure 1. Comparison of serum LDH activity (A) and serum lactate levels (B) ratios before and after four weeks of aerobic versus anaerobic exercise. Statistical analysis is performed using a T-test with a significance level of p < 0.05.



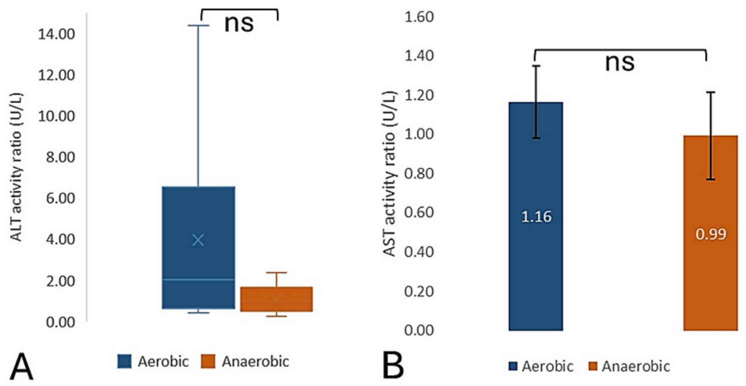
Furthermore, elevated levels of CK in the blood are often used as a biomarker for muscle injury, particularly related to exercise. The present study shows that the mean serum CK activity ratio in the aerobic group (0.58 ± 0.092 U/L) is significantly lower (t-test; p = 0.021) than in the anaerobic group (0.90 ± 0.088 U/L), as shown in Figure 2.

Figure 2. Comparison of serum CK activity ratio before and after four weeks of aerobic versus anaerobic exercise. Statistical analysis is performed using a T-test with a significance level of p < 0.05.



As an additional biomarker for muscle injury and representing liver function after four weeks of exercise, the ratio of ALT and AST activities does not show significant differences, as shown in Figure 3.

Figure 3. Comparison of serum ALT (A) and AST (B) activity ratios before and after four weeks of aerobic versus anaerobic exercise. Statistical analysis is performed using a Mann-Whitney test for A and a t-test for B with a significance level of p < 0.05.



Discussion

This study investigates the impact of aerobic and anaerobic exercise on muscle damage markers. Serum lactate dehydrogenase (LDH) activity significantly increases following both aerobic (540.19 ± 22.358 Umol/mL to 677.88 ± 50.223 Umol/mL; p = 0.028) and anaerobic exercise (460.26 ± 52.038 Umol/mL to 677.39 ± 66.238 Umol/mL; p = 0.027). This finding aligns with previous research demonstrating elevated LDH levels in response to muscle damage and exercise-related metabolic stress (Kanda et al., 2014; Mexis et al., 2023; Kim et al., 2022). However, contrary to expectations, serum lactate levels do not significantly change in either exercise group (aerobic: 2.14 ± 0.127 mmol/L to 2.40 ± 0.138 mmol/L; p = 0.252 vs. anaerobic 1.30 ± 0.099 mmol/L to 1.46 ± 0.097 mmol/L; p = 0.103). This suggests that in this context, lactate may not be a reliable marker for acute muscle injury following these types of exercise. This could be attributed to rapid lactate clearance post-exercise or efficient lactate metabolism during both aerobic and anaerobic activities (Li et al., 2022). The mean serum LDH activity ratio before and after exercise is lower in the aerobic group (1.26 ± 0.103) compared to the anaerobic group (1.68 ± 0.271), although this difference is not statistically significant. This suggests that while LDH levels increase with exercise, the type of exercise may not significantly influence the extent of this increase. Similarly, the mean serum lactate level ratio shows no statistically significant differences between the groups, indicating that lactate levels are similarly unaffected by the type of exercise performed.

Creatine kinase (CK) activity exhibits a differential response to exercise type. While aerobic exercise leads to a significant decrease in CK activity (8.55 ± 0.731 U/L to 4.70 ± 0.616 U/L; p = 0.003), anaerobic exercise does not result in a significant change (7.55 ± 1.231 U/L to 6.55 ± 0.967 U/L; p = 0.230). The mean serum CK activity ratio before and after exercise is significantly lower in the aerobic group compared to the anaerobic group (0.58 ± 0.091 vs. 0.90 ± 0.088; p = 0.02). This significant difference indicates greater muscle damage associated with anaerobic exercise, likely due to the intense, short-duration nature of these activities, which are known to cause more substantial muscle fiber disruption (Baird et al., 2012; Leite et al., 2023). The observed decrease in CK following aerobic exercise may reflect a protective adaptation of muscle tissue to sustained, lower-intensity activity (Latham et al., 2008), distinct from the response to high-intensity bursts (Darani et al., 2018).

Serum ALT and aspartate aminotransferase (AST) levels remain stable following both aerobic and anaerobic exercise. No significant differences between the groups are observed in the before and after exercise ratios of ALT and AST activities. These findings indicate that neither moderate aerobic nor anaerobic exercise significantly impacts liver function in this study population, supporting the safety of these exercise regimens for individuals without pre-existing liver conditions. This aligns with findings from a study investigating the effects of a 12-week aerobic exercise program on adult male athletes (football players) aged 21-24. While that study finds significant decreases in bilirubin and globulin levels following the intervention, it also reports no significant changes in alkaline phosphatase, AST, ALT, total protein, and albumin levels (p > 0.05) between the exercise and control groups (Bari et al., 2023). This reinforces the notion that moderate exercise, even over a longer duration, does not typically induce significant changes in these key liver enzymes.

This study has several limitations. Biomarker measurements are taken only at two time points (before and after four weeks of exercise). This limited sampling may not capture the full temporal dynamics of biomarker changes. Future studies should include more frequent measures to better understand these changes over time. Furthermore, potential confounding factors such as diet, sleep, and individual fitness levels are not controlled. Future research should incorporate these variables to provide a more comprehensive understanding of the factors influencing biomarker responses to exercise. Finally, the study population should be expanded to enhance the generalizability of the findings.

Conclusions

The present findings demonstrate that LDH and CK were sensitive biomarkers for detecting muscle injury induced by different types of exercise, while lactate appeared less reliable in this context. Moderate aerobic and anaerobic exercise did not significantly impact liver function. Future research should explore the mechanisms underlying the differential biomarker responses to exercise, including the roles of genetic factors, training status, and recovery strategies. Investigating other emerging biomarkers could further enhance the monitoring and managing of exercise-induced muscle injury.

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Authorship contribution statement

All authors listed in the manuscript declare significant contributions to the research, as outlined below:

Author 1: writing (original draft), visualization, validation, methodology, formal analysis, data curation, conceptualization, funding acquisition.

Author 2: supervision, writing (review & editing), validation, resources, project administration, methodology, investigation, conceptualization.

Author 3: writing (review & editing), validation, resources, methodology, investigation, conceptualization.

Author 4: writing (review & editing), validation, resources, methodology, investigation, conceptualization.

Declaration of Competing Interest

We declare no conflict of interest.

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