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Acute Effects of Moderate-Intensity Exercise on Plasma Free Fatty Acid Levels in Normal-Weight Women

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ABSTRACT

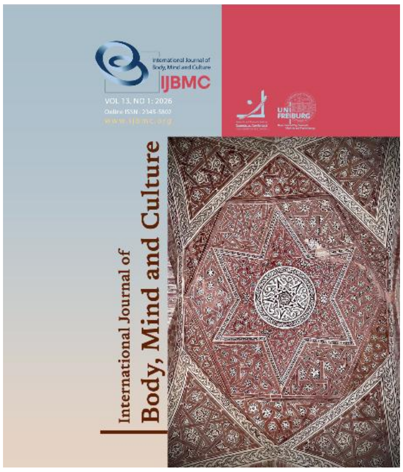
Objective: Physical activity supports metabolic health by enhancing energy metabolism, including lipolysis—the breakdown of fat stores into glycerol and free fatty acids. However, the impact of moderate-intensity ergocycle and circuit body weight training (CBWT) on FFA concentrations in adolescent women remains unclear. This study aimed to assess moderate-intensity ergocycle training and CBWT against free fatty acid concentrations on the process of lipolysis.

Methods and Materials: This study was to quasi experiment pretest-posttest group design. The subject of this study whose the 26 women aged 18- 23 years, divided into two groups randomly so that each group made up of 13 people. The first group (K_1) was an ergocycle training and the second group (K_2) was an exercise CBWT. Blood sampling was performed at baseline (pre) and 5 minutes post-exercise. ELISA was applied to evaluate the concentration of free fatty acids in all samples. Statistical analysis was applied using paired sample t-test and independent sample t-test with a significance level of 5%.

Findings: Resultsn showed that the concentration of free fatty acids in K_1 between pre and post (0.054±0.002 to 0.057±0.004 mmol/L, p=0.012, effect size (ES): 0.949). In K_2 (0.056±0.003 to 0.065±0.007 mmol/L, p=0.001, ES: 1.671). We also observed differences between groups (p < 0.001, ES: 1.403).

Conclusion: Both exercise models have been shown to improve free fatty acid concentrations. However, the CBWT model was found to be more effective than ergocycle in improving free fatty acid concentrations in normal-weight women.

Keywords: circuit body weight training (CBWT), ergocycle, free fatty acids, lipolysis, moderate-intensity exercise.



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Introduction

Physical activity is widely recognized as a cornerstone of metabolic health due to its broad effects on cardiovascular, hormonal, and energy-regulating systems (Myers et al., 2019). In the domain of lipid metabolism, exercise stimulates lipolysis. In this hormonally mediated process, triglycerides in adipose tissue are broken down into glycerol and free fatty acids (Lafortuna et al., 2008) to meet energy demands during exertion (Farsi & Ghahramani, 2020). This is primarily driven by catecholamines, such as epinephrine and norepinephrine, which activate hormone-sensitive lipase (HSL) and trigger FFA release into the bloodstream (McMurray & Hackney, 2005). Once mobilized, FFAs are transported to skeletal muscle and liver to be oxidized, especially when glucose reserves are limited (Gemmink et al., 2020). The plasma concentration of FFA is therefore a widely accepted biochemical marker of fat mobilization and is commonly used to assess metabolic responses to exercise (Henderson, 2021). In this context, FFA serves not only as a substrate but also as a reflection of metabolic flexibility and adaptation, especially in response to varied training modalities (Risikesan et al., 2023). Thus, examining how different exercise forms affect FFA concentrations can yield insights into how the body regulates energy usage based on activity type, intensity, and duration (Christensen et al., 2019).

Exercise modality is a key factor influencing metabolic responses, particularly those involving fat oxidation. Circuit Body Weight Training (CBWT), which involves structured, bodyweight-based functional movements, integrates both resistance and aerobic elements to improve strength, cardiovascular endurance, and metabolic efficiency (Archila et al., 2021). Its minimal equipment requirement and flexibility make CBWT a potentially accessible option, particularly for populations with limited access to fitness facilities. However, due to variability in execution and load control, its physiological effects may differ compared to structured aerobic modalities such as ergocycle training (Kumar & Dhull, 2023; Rezaei et al., 2024). Ergocycle training, in contrast, offers a standardized, intensity-controlled aerobic format commonly employed in exercise physiology research. Although both approaches are known to positively affect metabolic health, their mechanisms of action and physiological impacts may differ. Kim et al., (2018), for instance, demonstrated that circuit training effectively improved body composition and reduced markers of metabolic syndrome, particularly in obese female college students. Similarly, Lafortuna et al. (2008) found that ergocycle and treadmill training elicited distinct cardiometabolic responses, underscoring the importance of modality selection in designing effective interventions. In the present study, both exercise models were implemented at moderate intensity (64–76% HRmax) among healthy women aged 18–23 years, a population with high metabolic responsiveness, which allows for clearer observation of acute physiological changes in lipid metabolism during exercise.

Young adult women represent a critical population in preventive health strategies, as this demographic often exhibits transitional lifestyle patterns that may affect long-term metabolic outcomes (Göger & Cingil, 2022). Several previous studies have shown that moderate-intensity exercise can elevate plasma FFA levels as part of the body's acute metabolic response. For example, Despres et al. (1984) reported enhanced lipolytic activity following a 20-week structured ergocycle program, and Dyaksa et al. (2021) demonstrated that moderate-intensity ergocycle training significantly increased FFA concentrations in overweight women. Likewise, Paoli et al. (2021) found that circuit-based training combining resistance and aerobic elements led to reductions in regional fat thickness, suggesting elevated lipolysis. However, most existing studies focus on a single type of exercise, and direct comparisons between different training modalities remain limited, particularly among normal-weight young adult women, who represent a metabolically responsive group relevant for early preventive health strategies. The lack of comparative data between CBWT and ergocycle training in this population constrains our understanding of how exercise type modulates acute lipolytic responses, especially when measured objectively via plasma FFA levels.

Although various studies have examined the effects of individual exercise types on lipid metabolism, few have directly compared the efficacy of ergocycle and CBWT training in elevating FFA levels as an indicator of lipolysis, particularly in the context of young female populations. The absence of comparative data presents a significant research gap that warrants exploration to provide a scientific foundation for selecting training methods that optimize fat mobilization. Therefore, this study aims to compare the effects of moderate-intensity ergocycle and CBWT training on plasma FFA levels as a marker of lipolytic activity. The findings are expected to offer practical contributions to the fields of exercise physiology and metabolic health, especially in designing accessible, effective, and evidence-based training interventions for young women seeking to enhance fat oxidation efficiency. Therefore, this study hypothesizes that both moderate-intensity CBWT and ergocycle training will result in increased plasma FFA concentrations as an acute marker of lipolysis, with CBWT producing a relatively greater effect due to its combined muscular and cardiovascular demands. This hypothesis is grounded in the assumption that multimodal circuit training induces more widespread metabolic activation compared to single-mode aerobic exercise.

Methods and Materials

Study design and participants

This study employed a quasi-experimental pretest-posttest group design. The participants in this study were 26 healthy women aged 18–23 years, with no known metabolic diseases or cardiovascular conditions. They were randomly assigned into two equal groups of 13 participants each. The first group (K_1) underwent ergocycle training, while the second group (K_2) performed Circuit Body Weight Training (CBWT). All participants were informed about the study procedures and provided written informed consent prior to participation. Ethical approval for this study was obtained from the Ethics Committee of Universitas Airlangga, Surabaya (Approval No. 139/EC/KEPK/FKUA/2019).

Physical exercise protocol

This study was conducted at the Physiological Sciences Laboratory, Faculty of Medicine, Universitas Airlangga (Indonesia). Personal trainers guided all subjects to warm-up for 5 minutes at a low intensity of 50% HRmax before starting all core exercises (ergocycle and CBWT) using dynamic stretching. The first group performed moderate-intensity ergocycle exercise at 64-76% of maximum heart rate (HRmax), maintaining the moderate-intensity exercise for 30 minutes. The second group performed systematic and repetitive exercises using Circuit Body Weight Training (CBWT) at moderate-intensity (64-76% HRmax) for 30 minutes. After completing both exercise models, both groups performed a 5-minute cool down at a low intensity of 50% HRmax using PNF stretching. To prevent dehydration during the exercise intervention, 250 cc of mineral water was provided for the subjects to consume.

Blood sampling and free fatty acid analysis

Pre-test was conducted by taking blood samples from the arm (median cubital vein) after fasting overnight (± 10 hours). Post-test was conducted by taking blood samples from the arm (median cubital vein) 5 minutes immediately after the exercise intervention (ergocycle and CBWT). All blood samples obtained were taken to the laboratory for centrifugation to separate the plasma samples. The collected plasma was then immediately examined for Free Fatty Acid (Lafortuna et al., 2008) concentration using the ELISA Kits (Cat.No.: MBS268756; Human FFA, MyBioSource, Inc., Southern California, San Diego (USA)) with an ELISA Kit sensitivity level of up to 0.05 mmol/L and a detection range of 10 mmol/L-0.156 mmol/L. FFA concentration analysis was conducted at the Laboratory of Physiology, Faculty of Medicine, Brawijaya University (Indonesia).

Analysis

Statistical analysis in this study used the SPSS 20.0 version, data was presented mean and standard deviation. Descriptive statistical analysis to determine the characteristics of subjects and the variable measurement results before and after treatment. The normality test was performed using parametric statistics (shapiro-wilk test). Difference test to find out whether there was a difference in the mean of two samples (groups) that are paired or related to the paired sample t-test. The next different test was to find out whether there was a difference or comparison of the average of the two samples (groups) with the independent sample t-test.

Findings and Results

The results of the assessment of the characteristics of the research subjects did not find any significant differences in age, height, weight, body mass index (all $p > 0.05$) (Table 1). The results of examining blood free fatty acid levels before and after treatment in each group are presented in Figure 1.

Table 1

Description of the characteristics of the research subject

Variable	(K_1; n=13)	(K_2; n=13)	p-value
Age (yrs)	19.38 ± 1.04	19.08 ± 0.95	0.917
Height (m)	1.55 ± 0.05	1.54 ± 0.06	0.926
Weight (kg)	52.14 ± 5.75	53.31 ± 6.02	0.852
Body mass index (kg/m²)	21.58 ± 1.60	21.97 ± 1.29	0.964

Description: K_1: Ergocycle group; K_2: CBWT group. Data are presented as mean ± standard deviation (SDs). p-value was obtained by independent sample t-test analysis.

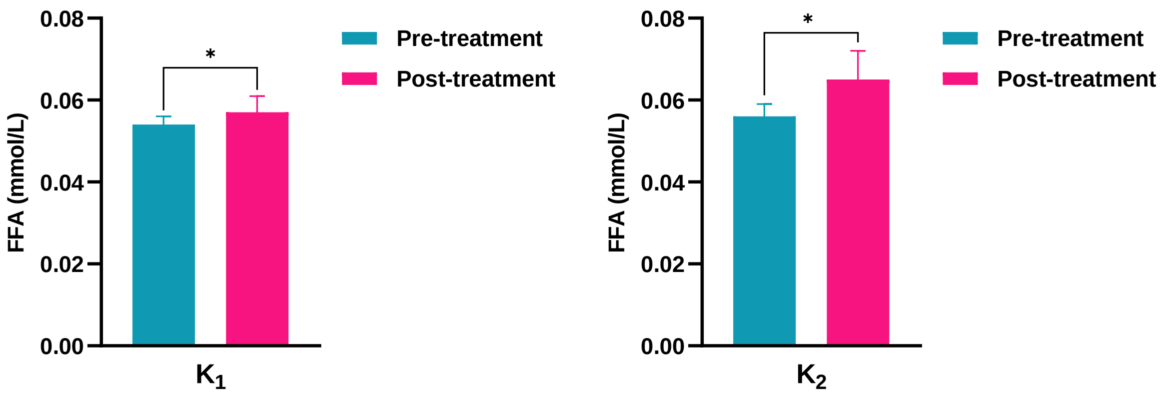

Figure 1

The results of examination of blood free fatty acid levels pre-treatment and post-treatment in each group.

Data are presented as mean ± standard deviation (SDs). p-value was obtained by paired sample t-test analysis. *Significant at pre in each group ($p < 0.05$).

Based on Figure 1, the results of examination of blood free fatty acid levels pre-treatment and post-treatment in K_1 (0.054 ± 0.002 to 0.057 ± 0.004 mmol/L; p=0.012; effect size (ES): 0.949), K_2 (0.056 ± 0.003 to 0.065 ± 0.007 mmol/L; p=0.001; ES: 1.671). Analysis of the differences in average levels of free fatty acids in the blood pre-, post-treatment and delta between groups are presented in Figure 2.

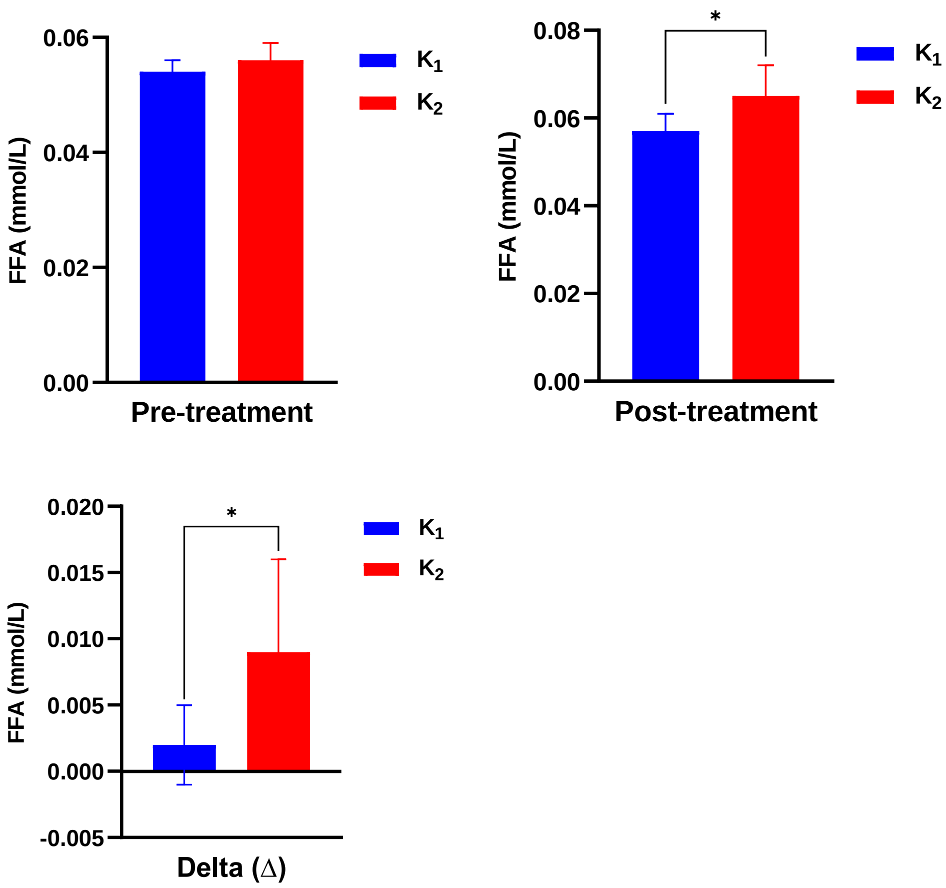

Figure 2

Analysis of the different levels of free fatty acids in the blood pre-, post-treatment and delta (Δ) between groups.

Data are presented as mean ± standard deviation (SDs). p-value was obtained by independent sample t-test analysis. *Significant at K_1 ($p < 0.05$).

Based on Figure 2, it can be seen that there was no observed difference in pre-treatment free fatty acid levels between pre-treatment K_1 (0.054 ± 0.002 mmol/L), with K_2 (0.056 ± 0.003 mmol/L) and ($p = 0.076$). There was a significant difference in post-treatment free fatty acid levels observed between K_1 (0.056 ± 0.005 mmol/L) and K_2 (0.065 ± 0.007 mmol/L), and ($p = 0.001$; ES: 1.479). Likewise, the results of observations on delta free fatty acids, we found a significant difference between K_1 (0.002 ± 0.003 mmol/L) and K_2 (0.009 ± 0.007 mmol/L), and ($p = 0.008$; ES: 1.299).

Discussion and Conclusion

The present findings indicate that a single session of moderate-intensity exercise, whether performed using an ergocycle or through circuit bodyweight training (CBWT), can acutely elevate plasma free fatty acid levels (Lafortuna et al., 2008). This response reflects short-term activation of lipolytic pathways and supports prior evidence that submaximal aerobic and mixed-modality exercise stimulates fat mobilization as part of the acute metabolic response. The greater increase in FFA observed in the CBWT group compared to the ergocycle group may be explained by the combined resistance and aerobic nature of circuit training. The involvement of multiple large muscle groups and intermittent high-effort movements in CBWT likely imposes a higher metabolic demand, which may enhance fat oxidation and systemic energy turnover (Gemmink et al., 2020; Petridou et al., 2005). Although hormonal mechanisms such as catecholamine-driven activation of hormone-sensitive lipase (HSL) are well established in the regulation of lipolysis (McMurray & Hackney, 2005), these pathways were not directly assessed in the present study. Therefore, any interpretation regarding their involvement remains speculative. Future research that includes hormonal and enzymatic markers is needed to clarify the physiological mechanisms underlying the observed differences between exercise modalities.

The alignment of these findings with prior research strengthens their validity. Tremblay et al., (1985) reported that structured aerobic training using ergocycle equipment over 20 weeks enhanced adipose tissue lipolytic capacity, which aligns with the FFA increase observed in the ergocycle group of this study. Similarly, Dyaksa et al. (2021) found that moderate-intensity ergocycle training significantly elevated FFA levels in overweight women, underscoring the relevance of equipment-based exercise in enhancing fat metabolism. However, in the present study, the effect was less pronounced than that of CBWT. In contrast, Paoli et al. (2021) showed that circuit training incorporating both resistance and endurance modalities significantly reduced regional fat thickness, suggesting systemic lipolytic activation. Taken together, these findings suggest that CBWT may serve as a viable, equipment-free training option that acutely stimulates fat mobilization, although further investigation is needed to confirm its long-term efficacy. The novelty of the present study lies in its direct, within-subject comparison of two exercise modalities applied at matched intensities in healthy young adult females, a demographic that remains underrepresented in acute lipolysis research.

These results may have preliminary implications for the development of accessible training strategies aimed at promoting fat utilization in young women, though their generalizability and long-term impact require further study. CBWT offers a flexible and efficient alternative in environments with limited access to fitness equipment, such as universities or community settings (Archila et al., 2021; Kumar & Dhull, 2023). Moreover, the combination of resistance and endurance elements in CBWT may provide metabolic benefits equal to or exceeding those of conventional aerobic exercise formats (Paoli et al., 2021). While the observed lipolytic response to CBWT is encouraging, it is not sufficient to infer preventive health benefits such as reductions in obesity or metabolic syndrome risk without longitudinal data. Theoretically, these findings also contribute to a broader understanding of how muscle contraction types and motor unit recruitment patterns during exercise influence lipid metabolism pathways, offering new directions for integrative research in exercise physiology.

Nevertheless, several limitations of this study should be acknowledged. First, the short-term experimental design, which measured FFA levels only at two time points (pre- and post-exercise within a single session), limits the generalizability of these results to chronic adaptations. As noted by (Holloszy & Coyle, 1984), acute metabolic responses do not necessarily reflect long-term physiological adaptations that may result from sustained training. Second, the sample was restricted to healthy young adult females, limiting applicability to other populations, such as males, older adults, or individuals with metabolic disorders. Third, although FFA is a valid marker of lipolytic activity, relying solely on this measure provides only a partial view of fat metabolism. Future studies should consider including additional biomarkers such as plasma glycerol concentration, lipolytic enzyme activity, or even imaging techniques to assess adipose tissue changes more comprehensively (Arner, 2005). Longitudinal research with larger, more diverse populations and repeated training exposures is recommended to better understand the sustained effects of CBWT and ergocycle exercise on lipolysis and overall metabolic health.

This study demonstrates that a single session of moderate-intensity exercise, whether performed using an ergocycle or through Circuit Body Weight Training (CBWT), acutely increases plasma free fatty acid (Lafortuna et al., 2008) concentrations in normal-weight young women, indicating a short-term lipolytic response. Although both exercise modalities were effective, CBWT elicited a comparatively greater increase in FFA levels. These findings suggest that multimodal circuit-based exercise may induce a more pronounced acute metabolic stimulus under submaximal conditions. However, given the acute nature of this intervention, further research is warranted to evaluate the long-term effects of these training modalities on lipid metabolism, hormonal responses, and body composition across diverse populations. Additionally, future studies should assess feasibility, adherence, and functional outcomes to better inform the integration of CBWT into clinical or fitness programming.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Ethical considerations in this study were that participation was entirely optional.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contribute to this study.

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