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Effect of post-training meals on blood glucose and blood pressure in young soccer athletes: Intervention and correlational study

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Abstract: Macronutrient content of post-exercise meal is a fundamental for achieving optimal recovery following exercise training. This study aimed to analyze the effects of a high-fat meal consumed after training on blood glucose and pressure levels in young male soccer athletes. Furthermore, examining the relationship among body composition variables was a secondary objective. A pre-post intervention study was conducted with 34 male soccer athletes (age: 16 ± 0.8 years). Participants consumed a high-fat meal (-45% of total intake 1061 kcal) immediately after strenuous training. Blood samples were collected at baseline, immediately post-training, and 1 h post-training to assess trends in blood glucose and pressure levels. Bioelectrical impedance analysis (BIA) was used to measure participant characteristics. Statistical analysis was performed using one-way repeated measures ANOVA followed by post hoc Bonferroni tests to determine significant differences between groups. Pearson correlation analysis was conducted to examine the relationships among the body composition variables. The average skeletal muscle mass and body fat percentage were approximately 59% and 24.6%, respectively. Glucose levels remained unchanged immediately after training but increased significantly by ~17% ($p < 0.001$) 1 h later. Systolic blood pressure (SBP) decreased by ~5% ($p = 0.03$) at 1 h post-training, while diastolic blood pressure (DBP) exhibited minimal change ($p = 0.06$). A correlation analysis indicated an inverse relationship between body mass and skeletal muscle mass, contrasting with the linear relationship between body mass and body fat. The results suggest that a high-fat meal consumed after exercise may lead to an increase in glucose levels 1 h post-exercise. The slight reduction in SBP observed 1 h post-training may represent a normal physiological response to exercise. Since the current study did not have the exercise-only group, further research is needed to confirm whether the change of the blood glucose levels was mainly from the diet.
Keywords: athletes, blood pressure, carbohydrate, glucose, soccer

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INTRODUCTION

Post-exercise nutrition is a key strategy for endurance athletes to replenish glycogen depleted during training (Kerksick et al., 2017; Mardiana et al., 2023). The nutritional content and timing are crucial factors for achieving optimal recovery. The International Society of Sports Nutrition recommends a high-carbohydrate diet for the rapid restoration of exercise-induced glycogen depletion

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(Kerksick et al., 2017). Carbohydrates are well-known for the primary macronutrient that stimulate blood glucose response, which facilitates the rapid uptake of glucose by exercised muscles to replenish glycogen stores (Murray & Rosenbloom, 2018). Variations in macronutrient composition have been reported to affect blood glucose levels differently, with high-fat meals showing a lesser increase in blood glucose compared to high-carbohydrate meals (Shin et al., 2009). This variation may influence glucose metabolism. In a study with healthy participants, high-fat post-exercise meals have shown similar glucose responses to low-fat meals (Fox et al., 2004). However, the effect of high-fat post-training meals on glucose levels in young soccer athletes remains unexplored.

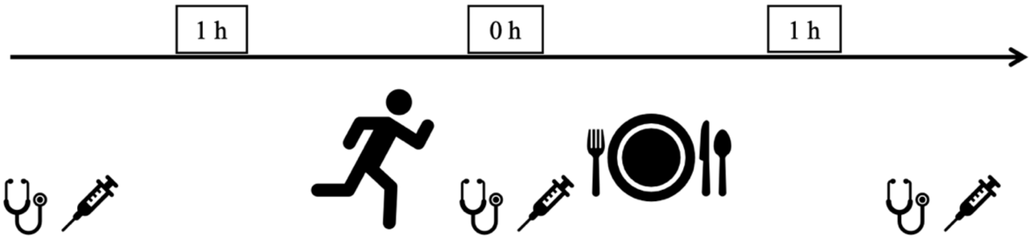

Figure 1. Study protocol.

Exercise training induces complex physiological responses involving hemodynamic, sympathetic nervous system, and thermodynamic changes, which in turn affect blood pressure regulation (Campbell et al., 2022; Cornelissen & Fagard, 2005; Katayama & Saito, 2019). Both systolic and diastolic blood pressures undergo dynamic changes during exercise (Wielemborek-Musial et al., 2016) and require time to return to baseline levels afterward (Cornelissen & Smart, 2013). A previous study have reported that post-exercise meals have minimal impact on blood pressure, showing only a slight reduction 1 h after cycling (Endo et al., 2016). The impact of high-fat post-exercise meals on physiological responses, including blood pressure, needs further investigation.

In the current study, we hypothesized that a post-training meal high in fat would alter blood glucose responses and blood pressure levels in young soccer players. Additionally, we investigated the correlations among body composition variables—specifically body mass, skeletal muscle mass, and fat mass—in young male soccer athletes, as these factors are crucial to monitor in endurance athletes

METHODS

Study design

A simple intervention trial was conducted, as depicted in Figure 1. Multiple blood tests and blood pressure measurements were performed at three time points: pre-exercise baseline, immediately after exercise, and 1 h post-training. Participants engaged in their regular strenuous training around 8:00 AM and were required to fast for 8 h before their pre-exercise blood samples were drawn. One hour before training, participants' pre-exercise blood pressure was recorded, and fasting blood glucose levels were measured from finger-stick samples. A second set of blood pressure and glucose measurements was taken prior to the post-training meal. Blood glucose levels were measured from finger-stick samples, while blood pressure was assessed using a digital monitor (Omron, Osaka, Japan). The training regimen included a 15-min warm-up, followed by 22 min of strenuous activity involving a sprinting-jogging interval of 10 s sprinting and 20 s jogging. The macronutrient composition of the provided meals was analyzed using the Indonesian version of the NutriSurvey food database, with the meal comprising 43% carbohydrates, 12% protein, and 45% fat with the total consumed energy 1061 kcal (Table 1).

Participants

The study was conducted at the Terang Bangsa soccer boarding school in Semarang, Indonesia. We included all young athletes aged 15 to 18 years. None of the participants were smokers, and none were on daily prescribed medications or special nutritional supplements.

Table 1. Nutrient analysis the food consumed by participants. The nutrient analysis was conducted using NutriSurvey food database Indonesian version.

Nutrients	Mean	% to total energy
Energy (kcal)	1061	
Carbohydrate (g)	139	43
Protein (g)	29	12
Fat (g)	52	45

Table 2. Participant Characteristics. The data were obtained by BIA.

Body composition (n = 34)	Mean	SD	Proportion to body weight (%)
Age (y)	16.0	0.8	
Body weight (kg)	61.7	8.4	
Height (cm)	167.7	5.5	
BMI (kg/m2)	22.0	2.8	
Total fat (kg)	15.2	3.9	24.6
Subcutaneous fat			
Whole body (kg)	10.8	2.8	17.5
Trunk (kg)	9.5	2.7	15.3
Arms (kg)	17.0	3.5	27.5
Leg (kg)	15.9	3.9	25.8
Skeletal muscle mass			
Whole body (kg)	36.5	1.9	59.1
Trunk (kg)	30.8	2.6	49.9
Arms (kg)	41.7	1.7	67.6
Legs (kg)	53.7	2.1	87.0

Anthropometric measurements

Body composition was measured using a self-calibrating bioelectrical impedance analyzer (BIA, Tanita DC 360, Japan). Height was measured with a medical stadiometer accurate to 0.1 cm (Quick Medical, Issaquah, WA). Body mass index (BMI) was automatically calculated by the BIA using the formula kg/m². To minimize precision errors associated with BIA, a 24-h standardization of dietary intake and physical activity was implemented prior to the study, aiming to minimizing precision error associated with BIA (Herberts et al., 2023).

Statistical analysis

One-way repeated measures ANOVA followed by post hoc Bonferroni tests was employed to analyze differences in mean values for the time effect. A significance level of $p < 0.05$ was used for all tests, and results are presented as means ± SD. Statistical analysis was conducted using SPSS software, version 27.0 (IBM, New York, United States).

RESULT AND DISCUSSION

Participant characteristics

All eligible participants (n = 34) were recruited, with an average age of 16 ± 0.8 y. Baseline characteristics of the participants are shown in Table 2. All participants had a BMI within the normal range (22.0 ± 2.8) kg/m^2, with total body fat averaging approximately 24.6% and subcutaneous fat around 17.5%. The total skeletal muscle mass was approximately 59%, with the highest proportion found in the legs (87%), followed by the arms (68%) and trunk (50%).

The effect of post-training meal on blood glucose levels

The levels of blood glucose are shown in Figure 2. Following exercise training, blood glucose levels exhibited a minimal change from baseline (-3%, $p > 0.05$). One hour after the exercise training, during which a meal was consumed, blood glucose levels increased by approximately 16% ($p < 0.001$) from baseline and by about 21% ($p < 0.001$) from immediately after the exercise.

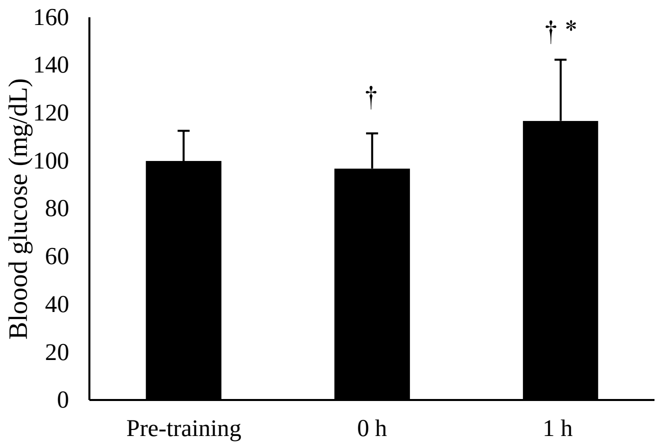

Figure 2. Blood glucose levels at baseline, 0 h and 1 h after an acute strenuous training. † $p \leq 0.05$ compared to pre-exercise baseline. * $p \leq 0.05$ compared to 0 h data. Data are presented as mean ± SD.

The effect of post-training meal on blood pressure levels

SBP levels continuously decreased, as shown in Figure 3A. There was a small but significant reduction in SBP immediately after exercise training (-3%, $p = 0.04$), and this decrease persisted, reaching -5% ($p = 0.003$) at 1 h post-exercise. In contrast, DBP (Figure 3B) remained stable both immediately and 1 h after exercise training ($p > 0.05$).

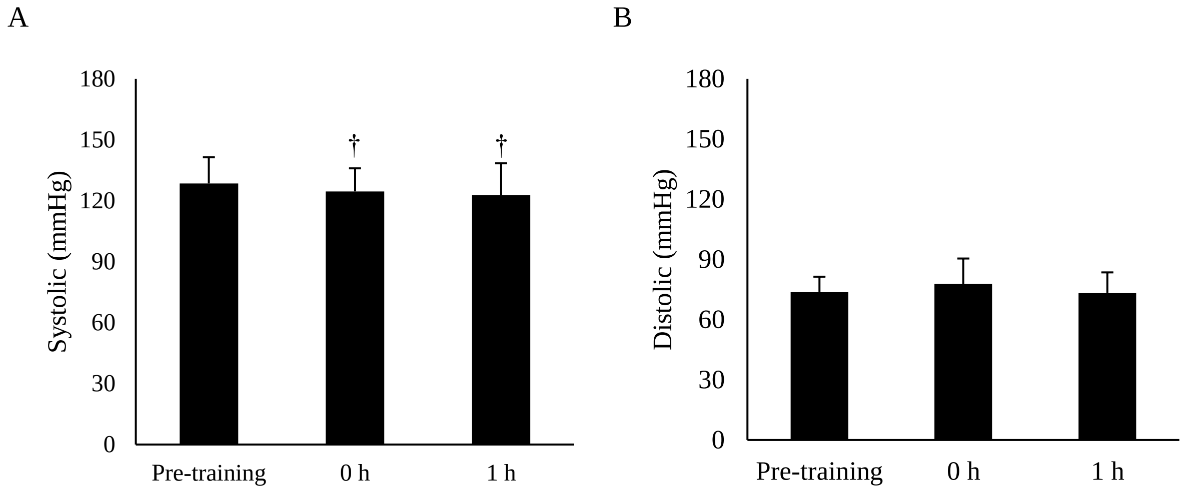

Figure 3. Systolic (A) and diastolic (B) blood pressure levels at baseline, 0 h and 1 h after an acute strenuous training. † $p \leq 0.05$ compared to pre-exercise baseline. Data are presented as mean ± SD.

The relationship among body compositions

Body weight, skeletal muscle, and body fat are key components in monitoring athletic health and performance. Figure 4 illustrates the relationships between body weight and skeletal muscle (4A), and between body weight and total body fat (4B). Skeletal muscle mass was moderately negative correlated with body weight (r = -0.68). In contrast, body weight showed a moderate positive correlation with total body fat (r = 0.77).

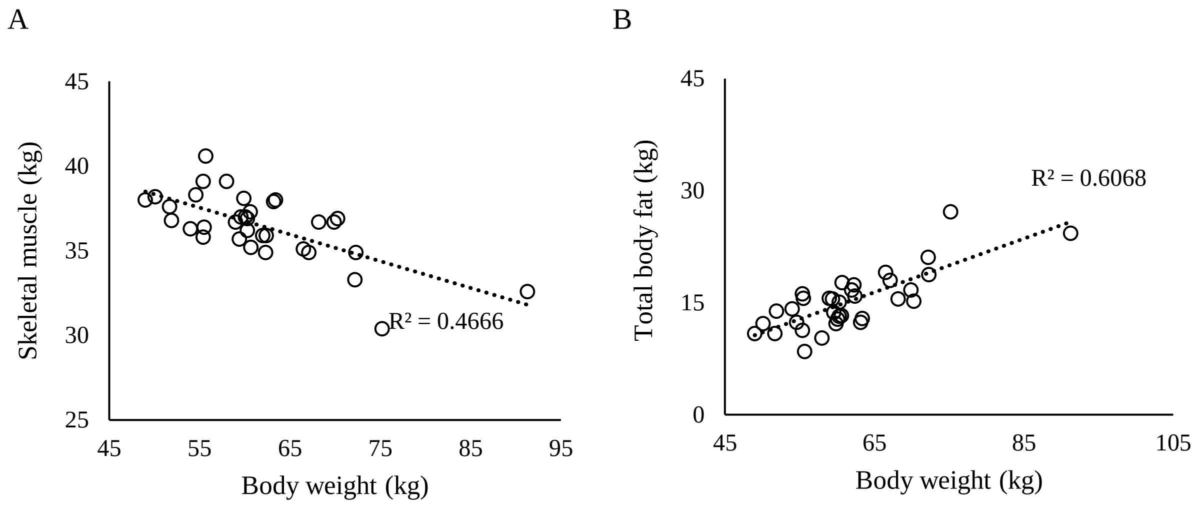

Figure 4. A regression analysis of body composition. The association between body weight and skeletal muscle (A) showed an opposite association to body weight and total body fat (B).

Post-exercise meal may associate with biomarker association

Figure 5 shows the association between SBP and blood glucose levels before training (A) and 1 h after training (B). Blood glucose and SBP levels were tend to be negatively associated at pre-training state (r = -0.19). This relationship changed after the consumption of a post-training meal. One hour after exercise training, a positive association was observed between blood glucose and SBP (r = 0.17). However, the correlation between blood glucose and SBP was likely minimal.

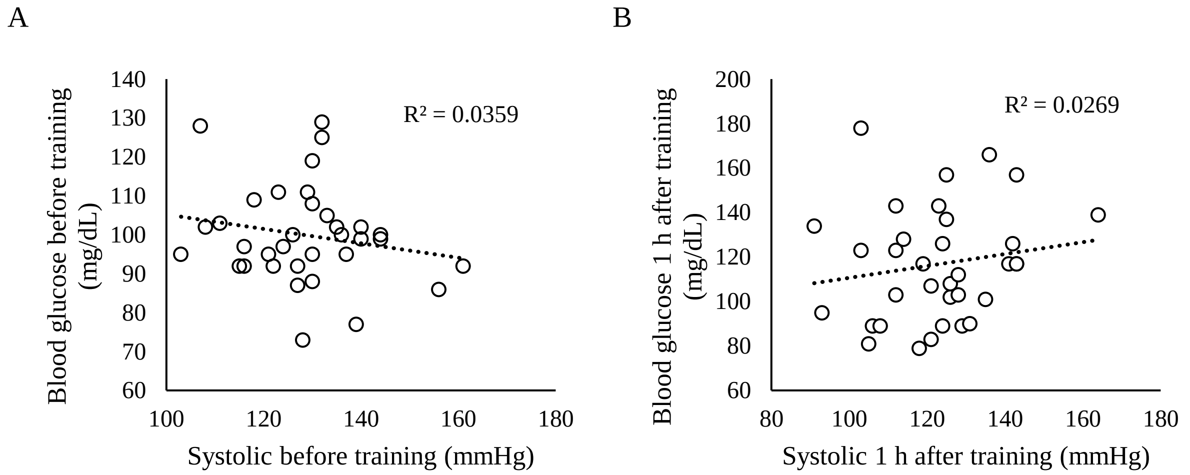

Figure 5. A regression analysis of blood glucose and blood pressure at pre-exercise baseline (A) and 1 h post exercise (B).

A post-training meal is critical for promoting muscle recovery after training (Beelen et al., 2010; Moore, 2015). It is well established that carbohydrate-rich meals effectively replenish glycogen stores depleted during exercise (Burke et al., 2011). While carbohydrates remain the primary source for glycogen resynthesis by stimulating blood glucose level rising, recent research suggests that consuming high-fat meals post-exercise may improve glucose response in subsequent training sessions (Areta et al., 2020), and therefore it may influence the glucose uptake. This study examines the effects of high-fat meals on blood glucose levels immediately following exercise training in young soccer athletes, with an additional focus on blood pressure as a measure of endothelial function. Body composition variables in the current study was an additional information. The current study found the key findings, which are: 1) Blood glucose levels increased by approximately 17% post-training; 2) SBP progressively decreased for up to 1 h post-training; and 3) Skeletal muscle mass was negatively correlated with body weight, while body fat was positively correlated with body weight.

We observed elevated blood glucose levels 1 h after strenuous exercise training, likely due to the post-training meal response. In healthy individuals, glucose metabolism typically normalizes within 1 h following high-intensity exercise training, after an initial slight decrease immediately post-exercise (Shambrook et al., 2018). Based on pre-exercise baseline levels, participants in the current study maintained normal blood glucose levels. The slight decrease immediately post-exercise reflects a normal physiological response, as glucose is taken up by the working skeletal muscles (Richter et al., 2001). The increase in blood glucose levels 1 h after exercise training remained within the normal range, according to the International Diabetes Federation guidelines (Bergman et al., 2024).

SBP exhibited dynamic changes during exercise (Nakamura et al., 2021). These changes reflect the complex response to increased cardiac output, sympathetic activation, shifts in vascular resistance, and thermoregulatory adjustments, all of which enhance blood flow to the working muscles (Campbell et al., 2022; Cornelissen & Fagard, 2005; Katayama & Saito, 2019). Previous studies in healthy individuals have shown that SBP rises proportionally with workload during exercise (Wielemborek-Musial et al., 2016) and decreases within 60 min post-exercise (Forjaz et al., 1998). Factors such as age and individual status can influence post-exercise blood pressure, as muscle vascularity and baroreceptor sensitivity are affected by aging (Monahan, 2007) and training status (Monahan et al., 2000). In the current study, SBP fell by approximately 5% at 1 h after 22 min of strenuous training—a minimal decrease, consistent with previous research showing small reductions in post-exercise SBP following both short and long-duration exercise (Guidry et al., 2006). This may represent part of the physiological response in athletes. Meanwhile, DBP remained stable post-exercise, possibly due to vasodilation in the arterioles or capillary sphincters of the exercised muscles, as well as reduced peripheral resistance (Laukkanen & Kurl, 2012).

In our participants, we observed an intriguing trend: increases in body weight were more strongly associated with gains in body fat than in skeletal muscle. This finding highlights the importance for athletes to monitor their body composition carefully and focus on promoting skeletal muscle growth. The current study underscores the importance of nutritional awareness for athletes, coaches, and sports nutritionists. Meal timing after exercise training should be fully considered. A previous study has shown that providing a nutritional meals immediately after exercise can enhance leg protein synthesis by threefold compared to delaying meals for 3 h post-exercise (Levenhagen et al., 2001).

Our current data serve as a foundation for investigating the effects of high-fat meals on exercise recovery, particularly their role in stimulating glucose uptake. Carbohydrates and proteins are well-recognized as essential substrates for glycogen restoration and muscle repair after exhaustive exercise (Ivy et al., 2008), yet the influence of post-exercise high-fat meals on recovery mechanisms remains an area requiring further investigation. Specifically, such meals may promote ketogenesis, a physiological response driven by enhanced fatty acid oxidation. Future research is required to quantify the production of ketone bodies resulting from the current fat percentage in post-exercise meals and to investigate their role in the recovery process. Emerging evidence highlights the relevance of ketone bodies in exercise recovery (Holdsworth et al., 2017; Poffé et al., 2019; Vandoorne et al., 2017). For instance, Holdsworth et al. (2017) demonstrated that exogenous ketone supplementation enhances endogenous insulin secretion, glucose uptake, and muscle glycogen synthesis, suggesting potential benefits that merit further investigation (Holdsworth et al., 2017).

Providing a high-fat meal after exercise necessitates careful consideration of its potential adverse effects, as it may affect both recovery and overall comfort. High-fat meals are known to slow gastric emptying, which can lead to bloating and discomfort, particularly in individuals with sensitive digestive systems. This delayed gastric emptying may also contribute to heartburn, as fats relax the lower esophageal sphincter, allowing stomach acid to move back into the esophagus. Additionally, some individuals may experience nausea, as the digestive system can become overwhelmed when processing a high-fat load, especially following intense physical activity when gastrointestinal motility may already be compromised. Given these potential side effects, it is essential for athletes, coaches, and sports practitioners to critically evaluate the tolerability of high-fat meals in post-exercise nutrition plans. Such assessments should include monitoring gastrointestinal symptoms, assessing individual variability in tolerance, and considering alternative dietary strategies if adverse effects are reported. During studies investigating the role of high-fat meals in post-exercise recovery, detailed documentation of side effects is crucial to ensure both the safety and efficacy of the intervention. This approach can help refine nutritional recommendations, ensuring they support optimal recovery without compromising athlete comfort or performance.

The major limitations of the current study are: 1) Since all activities were part of the regular monthly schedule at the soccer boarding school, we determined that ethical approval was not required; 2) The absence of a control group that performed exercise training without a post-exercise meal. As a result, we cannot definitively conclude that the changes in glucose levels were solely due to the post-training meal. This study aimed to gather preliminary data of the acute effect of post-exercise meal with high-fat content to support the need for a randomized controlled trial, including additional glucose metabolism parameters for further confirmation. A follow-up study is essential to investigate whether post-training meals influence the normalization of blood glucose levels. This can be achieved by incorporating additional time points for blood sample collection, allowing for a more detailed analysis of glucose dynamics. Consequently, the impact of high-fat meals on the return to baseline post-exercise blood glucose levels could be comprehensively clarified. Additionally, studying the impact of varying macronutrient compositions on glucose metabolism will be crucial for understanding the physiological responses in young endurance athletes

CONCLUSSION

Our main finding in this study is that a post-exercise meal with high fat content may modulate glucose responses. However, post-exercise systolic blood pressure appears to be regulated independently of the post-training meal, likely influenced by cardiovascular and autonomic factors rather than nutritional intake. Future studies involving athletes are needed to confirm the effectiveness of a high-fat post-exercise meal on recovery. Additionally, a secondary outcome of the study revealed a tendency for the ratio of skeletal muscle to body weight to decrease, while the opposite trend was observed in the relationship between body fat and body weight.

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CONFLICT OF INTEREST

There is no conflict of interest declared.

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