

Effect of 10 weeks of futsal training on Castelli Risk Index I and II, Atherogenic Index Plasma and Atherogenic Coefficient in Inactive Obese Boys

Berivan Jalal Rashid 

Department of Sport Science for Health and Performance, College of Physical Education and Sport Sciences, University of Halabja, Halabja, Kurdistan region, Iraq.

Naser Rostamzadeh *

Department of Physical Education and Sport Sciences, Faculty of Humanities and Social Sciences, University of Kurdistan, sanandej, Iran.

* Corresponding Author: naserrostamzadeh806@gmail.com.

How to Cite: Jalal Rashid, B., & Rostamzadeh, N. (2026). Effect of 10 weeks of futsal training on Castelli Risk Index I and II, Atherogenic Index Plasma and Atherogenic Coefficient in Inactive Obese Boys, *Journal of New Approaches in Exercise Physiology*, 8(16), 5-23.

DOI: 10.22054/nass.2026.91712.1232

Abstract

Purpose: Adolescent obesity is associated with early alterations in lipid metabolism and increased cardiovascular risk. Atherogenic indices such as Castelli Risk Index I (CRI-I), Castelli Risk Index II (CRI-II), Atherogenic Index of Plasma (AIP), and Atherogenic Coefficient (AC) are considered sensitive predictors of cardiovascular disease beyond traditional lipid measures. Therefore, the present study aimed to investigate the effect of 10 weeks of futsal training on selected atherogenic indices in inactive obese adolescent boys. **Method:** This quasi-experimental study was conducted using a pretest–posttest design with a control group. Thirty inactive obese boys aged 13–17 years were randomly assigned to an experimental group (futsal training, $n = 15$) and a control group ($n = 15$). The experimental group participated in a structured 10-week futsal training program, while the control group maintained their usual daily activities. Atherogenic indices were calculated from fasting lipid profiles measured before and after the intervention. Data were analyzed using paired-samples t-tests, independent-samples t-tests, and ANCOVA. **Results:** Within-group analysis revealed significant reductions in the experimental group for CRI-I ($p=0.021$), CRI-II ($p=0.012$), AIP ($p=0.011$), and AC ($p=0.032$), whereas no significant changes were observed in the control group ($p>0.05$). Between-group comparisons at posttest showed significant differences favoring the experimental group for CRI-I ($p=0.013$), CRI-II ($p=0.024$), AIP ($p=0.041$), and AC ($p=0.032$). These differences remained significant after adjusting for baseline values. **Conclusion:** Ten weeks of structured futsal training significantly improved atherogenic risk indices in inactive obese adolescent boys. Futsal may therefore serve as an effective, practical, and non-pharmacological strategy to reduce early cardiovascular risk in this population.

Keywords: Adolescent obesity; Futsal training; Atherogenic indices; Lipid profile; Cardiovascular risk.

Introduction

Adolescent boys with sedentary lifestyles and low levels of physical activity are increasingly recognized as a population at high risk for obesity and metabolic disorders (Smith & Jones, 2020). Physical inactivity in this group is strongly associated with higher body mass index (BMI), increased visceral adiposity, and unfavorable alterations in glucose metabolism (Fasihi, Agha-Alinejad, Gharakhanlou, & J Amaro Gahete, 2025; Regufe, Pinto, & Perez, 2020). Inactive obese boys often exhibit chronic low-grade inflammation, impaired lipoprotein profiles, and reduced insulin sensitivity compared to their more active peers (Lee et al., 2021). These unfavorable metabolic characteristics not only negatively affect quality of life and psychological well-being in the short term, but also significantly increase the likelihood of developing cardiovascular and metabolic diseases later in life (Martinez & Rodriguez, 2018). Given the rising prevalence of sedentary behaviors and obesity in youth populations worldwide, it is crucial to investigate effective interventions to improve metabolic health outcomes in this vulnerable group (Patel & Kumar, 2022).

Castelli Risk Indexes, including CRI-I (total cholesterol to HDL ratio) and CRI-II (LDL to HDL ratio), are widely accepted biomarkers for evaluating cardiovascular risk in both clinical and research settings (Anderson et al., 2017). Elevated values of these ratios reflect an imbalance in lipoprotein metabolism that predisposes individuals to atherogenesis and cardiovascular events (Brown & Clark, 2018). Several studies have reported that regular physical activity, especially aerobic exercise, can significantly improve Castelli Risk Indexes by increasing HDL levels and reducing LDL concentrations (Davis et al., 2021). Nguyen, Tran, and Le (2023) found that a 12-week futsal training program significantly reduced both CRI-I and CRI-II in overweight adolescents (Nguyen et al., 2023). Similarly, Silva et al. (2024) reported that moderate-intensity futsal training increased HDL and improved ratios of lipid biomarkers associated with Castelli Risk (Silva et al 2024). However, other research has produced conflicting

evidence. Martinez, Santos, and Lopez (2023) observed that eight weeks of physical training in obese adolescents did not lead to statistically significant changes in CRI-I and CRI-II, suggesting that specific training protocols or population characteristics may influence outcomes (Martinez, et al 2023). These inconsistent findings highlight the need for more targeted research to clarify the effects of futsal and similar team-based exercise interventions on Castelli risk measures among inactive obese boys.

The Atherogenic Index of Plasma (AIP) - calculated as the logarithm of the triglyceride to HDL ratio — and the Atherogenic Coefficient (AC) - the ratio of LDL to HDL - are also recognized as reliable predictors of atherosclerotic risk (Foster et al., 2019). Higher values of AIP and AC are associated with increased proportions of small dense lipoproteins and greater risk of cardiovascular events (Green & Black, 2020; Hernandez et al., 2021). Regular exercise is thought to beneficially modulate these indices by enhancing lipid metabolism and reducing triglyceride levels (Ivanov et al., 2022). Kim, Park, and Choi (2023) reported significant decreases in AIP and AC following consistent soccer training in obese adolescents (Kim et al., 2023). Jafari, Hosseini et al., (2025) found that 10 weeks of futsal training significantly reduced AIP in overweight adolescent boys (Jafari et al., 2025). In contrast, Rodriguez, Herrera, and Garcia (2024) showed that traditional aerobic exercise did not produce significant changes in AIP compared to a control group (Rodriguez et al., (2024). The presence of both positive and inconclusive results underscores the need for further investigation into how futsal and sport-based activities influence atherogenic indices, particularly among sedentary obese youth.

Given the rapid increase in obesity and sedentary behaviors among children and adolescents, it is essential to understand the potential cardiometabolic benefits of structured physical activity such as futsal. While some evidence supports the positive effects of futsal and other sport-related training on lipid-based risk markers, the conflicting findings reported in previous studies indicate a gap in the literature. Therefore, the present study aims to examine the effects of 10 weeks of

futsal training on CRI-I, CRI-II, AIP, and AC in inactive obese boys in order to contribute more definitive evidence for the design of effective physical activity interventions targeting cardiovascular risk reduction in this population.

Methods

Research Design and Participants

This study was conducted using a quasi-experimental design with a pretest–posttest design and a control group. The statistical population consisted of inactive obese boys. After explaining the research objectives and obtaining informed consent, 30 eligible participants were enrolled in the study and randomly assigned into two equal groups: 15 participants in the experimental group (futsal training) and 15 participants in the control group. Atherogenic indices including CRI-I = $(TC/HDLc)$ and CRI-II = $(LDLc/HDLc)$, AIP = $\{\log(TG/HDLc)\}$ and AC = $\{(TC-HDLc)/HDLc\}$ parameters were calculated before and after the intervention.

Futsal Training Protocol

The exercise protocol consisted of 10 weeks of futsal training for the experimental group. Training sessions were performed regularly and progressively. Each session included a warm-up (general and specific movements), a main part (futsal-based drills such as small-sided games, technical–tactical exercises, and futsal-specific interval activities), and a cool-down (stretching exercises and return-to-baseline activities). Training intensity and volume were adjusted according to participants' physical condition. The control group did not participate in any structured exercise program during the study period and maintained their usual daily activities.

Blood Sampling Procedure

To assess the biochemical variables, venous blood samples were collected at baseline and after the intervention. Blood sampling was performed following 10–12 hours of overnight fasting, under similar environmental conditions and at a consistent time of day. Participants were instructed to refrain from vigorous physical activity for 48 hours prior to sampling. Blood samples were centrifuged, and serum was used to determine lipid profile variables including total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). Subsequently, CRI-I, CRI-II, AIP, and AC were calculated using standard formulas.

Inclusion criteria were: being male, classified as obese according to the anthropometric criteria of the study, physically inactive (no regular exercise participation in recent months), free from metabolic and cardiovascular diseases, and not using medications or supplements affecting lipid metabolism. Exclusion criteria included: absence from training sessions, occurrence of injury or illness during the intervention, significant changes in dietary habits or initiation of additional exercise programs, and use of interfering medications or supplements during the study.

Statistical Analysis

For statistical analysis, normality of data distribution was assessed using the Shapiro–Wilk test. Within-group comparisons (pretest vs. posttest) were performed using the paired-samples t-test, and between-group comparisons were conducted using the independent-samples t-test. When necessary, analysis of covariance (ANCOVA) was applied to control for baseline values. The level of statistical significance was set at $p \leq 0.05$, and analyses were conducted using statistical software SPSS.

Results

The normality of data distribution was assessed using the Shapiro–Wilk test, and all variables demonstrated normal distribution ($p>0.05$). Therefore, parametric statistical analyses were applied. At baseline, there were no significant differences between the experimental (futsal training) and control groups in anthropometric characteristics and biochemical variables ($p>0.05$). Descriptive characteristics of participants are presented in Table 1.

Table 1. Anthropometric characteristics of participants (Mean \pm SD)

Variable	Experimental Group	Control Group	p-value
Age (years)	15.08 \pm 1.32	15.21 \pm 1.27	0.781
Height (cm)	165.42 \pm 7.85	166.94 \pm 8.11	0.863
Weight (kg)	80.36 \pm 6.74	81.12 \pm 6.03	0.815
BMI (kg/m ²)	30.08 \pm 2.34	30.41 \pm 2.29	0.742
Body Fat (%)	31.92 \pm 3.46	32.37 \pm 3.28	0.694

Within-group analysis using the paired-samples t-test showed that, after 10 weeks of futsal training, the experimental group experienced significant reductions in CRI-I ($p = 0.021$), CRI-II ($p=0.012$), AIP ($p=0.011$), AC ($p=0.032$), TC ($p=0.014$), TG ($p=0.041$), and LDL-C ($p=0.023$), along with a significant increase in HDL-C ($p=0.011$). In contrast, the control group demonstrated no significant changes in CRI-

I ($p=0.391$), CRI-II ($p=0.442$), AIP ($p=0.473$), AC ($p=0.451$), TC ($p=0.422$), TG ($p=0.483$), HDL-C ($p=0.676$), or LDL-C ($p=0.515$). Between-group comparisons revealed no significant differences at baseline for CRI-I ($p=0.132$), CRI-II ($p=0.543$), AIP ($p=0.854$), AC ($p=0.752$), TC ($p=0.369$), TG ($p=0.543$), HDL-C ($p=0.753$), or LDL-C ($p=0.258$); however, significant posttest differences were observed in favor of the experimental group for CRI-I ($p = 0.013$), CRI-II ($p=0.024$), AIP ($p=0.041$), AC ($p=0.032$), TC ($p=0.022$), TG ($p=0.011$), HDL-C ($p=0.031$), and LDL-C ($p=0.033$), which remained significant after adjustment for baseline values using ANCOVA ($p<0.01$).

Table 2: Changes in Lipid Profile and Atherogenic Indices After 10 Weeks (Mean \pm SD)

Variable	Group	Pretest (Mean \pm SD)	Posttest (Mean \pm SD)	p - value
CRI-I=log (TG/HDL-C)	Experimental	4.78 \pm 0.58	3.84 \pm 0.49	0.021
	Control	4.89 \pm 0.61	4.82 \pm 0.63	0.391
p -value (Between-Group)		0.132	0.013	-
CRI-II= LDL/HDL	Experimental	3.08 \pm 0.46	2.33 \pm 0.37	0.012
	Control	3.15 \pm 0.49	3.11 \pm 0.51	0.442
p -value (Between-Group)		0.543	0.024	-
AIP=log (TG/HDL-C)	Experimental	0.59 \pm 0.08	0.39 \pm 0.06	0.011
	Control	0.60 \pm 0.09	0.58 \pm 0.08	0.473
p -value (Between-Group)		0.854	0.041	-

AC={ (TC-HDLc)/HDLc }	Experimental	3.78 ± 0.58	2.84 ± 0.49	0.032
	Control	3.89 ± 0.61	3.83 ± 0.64	0.451
P (Between-Group)		0.752	0.032	-
TC (mg/dL)	Experimental	196.84 ± 17.95	178.26 ± 15.42	0.014
	Control	199.73 ± 18.12	197.84 ± 17.66	0.422
p -value (Between-Group)		0.369	0.022	-
TG (mg/dL)	Experimental	162.48 ± 23.16	138.74 ± 19.88	0.041
	Control	165.91 ± 22.84	163.57 ± 23.11	0.483
p -value(Between-Group)		0.543	0.011	-
HDL-C (mg/dL)	Experimental	41.12 ± 4.63	46.38 ± 4.91	0.023
	Control	40.88 ± 4.51	41.03 ± 4.66	0.676
p -value (Between-Group)		0.753	0.031	-
LDL-C (mg/dL)	Experimental	126.73 ± 14.82	108.15 ± 12.94	0.011
	Control	128.64 ± 15.11	127.22 ± 15.43	0.515
p -value (Between-Group)		0.258	0.033	-

Discussion

Childhood and adolescent obesity is associated with early disturbances in lipid metabolism and an increased risk of cardiovascular diseases, and these changes may occur before the clinical manifestations are evident (D'Adamo et al., 2015). In recent years, atherosclerogenic indices derived from lipid ratios have been proposed as more sensitive markers of cardiovascular risk compared to individual blood lipid values (Racil et al., 2023). This study aimed to examine the effects of 10 weeks of futsal training on atherosclerogenic indices and the lipid profile in sedentary obese adolescent boys. The main findings revealed that structured futsal training significantly improved CRI-I, CRI-II, AIP, and AC, alongside favorable changes in traditional lipid markers, while no significant changes were observed in the control group. These results suggest that small-sided recreational team sports may serve as an effective non-pharmacological strategy to improve cardiovascular health in obese adolescents.

CRI-I, which represents the ratio of total cholesterol to HDL-C, was significantly reduced after the intervention, indicating an improvement in the balance between atherogenic and anti-atherogenic lipoproteins. This finding is consistent with previous studies showing reductions in cholesterol-related risk ratios following aerobic and interval training in obese youth (Arazi et al., 2013; Tjønnå et al., 2009). In agreement with the results of this study, Racil et al. (2023) conducted a study titled Long- and Short-Term High-Intensity Interval Training on Lipid Profile and Cardiovascular Disorders in Obese Male Adolescents, and reported that high-intensity interval training (HIIT) in obese adolescent boys leads to significant improvements in lipid-related indices and a reduction in cardiovascular risk (Racil et al., 2023). In contrast, da Silva et al. (2020) in their study titled Short-term High-Intensity Interval Training Does Not Improve Body Composition and Cardiovascular Risk Factors in a Sample of Overweight and Obese Men reported that a short-term HIIT intervention did not produce meaningful changes in

cardiovascular risk factors and lipid profiles (da Silva et al., 2020). Potential reasons for this discrepancy include differences in age (adolescents versus adults), maturation status, hormonal background, and the "type of activity" since futsal, being a small-sided game involving intermittent play and high motivation, typically creates a different training load and participant behavior compared to classic HIIT protocols (Sun et al., 2024).

In this study, CRI-II, which is calculated as the ratio of LDL-C to HDL-C, also decreased significantly. This ratio is considered a strong predictor of the progression of atherosclerosis (Millán et al., 2009). The reduction observed in this study aligns with findings from interval training and team sports interventions in adolescents (Buchan et al., 2011). Racil et al. (2023) also reported that HIIT can improve metabolic and lipid markers in obese adolescent boys and is generally associated with a reduction in cardiovascular risk (Racil et al., 2023). On the other hand, Sun et al. (2024) in their study titled *Effect of Eight-Week High-Intensity Interval Training Versus Moderate-Intensity Continuous Training Programme on Body Composition, Cardiometabolic Risk Factors in Sedentary Adolescents* reported that, although HIIT and MICT improved certain body composition components, no significant between-group differences were found for many clinical biomarkers, which is not consistent with the results of this study (Sun et al., 2024). This discrepancy may be due to differences in weight/obesity status (inactive obese adolescents versus sedentary adolescents with normal weight), baseline lipid levels, and lower sensitivity of cholesterol ratios in shorter periods or individuals with milder lipid abnormalities (Giovanelli et al., 2025).

Another significant result of this study was the reduction in AIP. The decrease in AIP observed here is clinically important, as AIP is a marker of a more atherogenic profile (including an increase in small, dense LDL particles) and higher cardiovascular risk. This result is supported by studies that show that high-intensity interval training reduces triglycerides while increasing HDL-C, thus lowering AIP (Tjønnå et al., 2009; Krstrup et al., 2010). In line with these findings, Giovanelli et

al. (2025) reported in their study titled *Metabolic Improvement After Exercise Training in Children with Obesity: Possible Role of the Six-Minute Walking Test* that after a supervised exercise program, improvements in aerobic capacity were associated with improved metabolic profiles, including a reduction in atherogenic plasma indices (Giovanelli et al., 2025). Similarly, Sun et al. (2024) in their study *Effect of Eight-Week High-Intensity Interval Training Versus Moderate-Intensity Continuous Training Programme on Body Composition, Cardiometabolic Risk Factors in Sedentary Adolescents* reported that, despite some improvements (particularly in triglycerides in the HIIT group), no substantial between-group differences were found for clinical biomarkers (Sun et al., 2024). A possible explanation for this is that AIP is highly dependent on simultaneous changes in TG and HDL, so differences in diet control, actual exercise intensity, and baseline TG levels could determine whether sufficient changes to reduce AIP occur (Horváth et al., 2024).

The atherogenic coefficient, which represents the ratio of non-HDL cholesterol to HDL-C, also significantly decreased following futsal training. This indicates a global reduction in atherogenic lipoproteins relative to the protective HDL. Horváth et al. (2024) reported that even a six-week period of aerobic exercise (at varying intensities) can improve biochemical markers, including lipids, in individuals with severe obesity (Horváth et al., 2024). However, da Silva et al. (2020) in their study *Short-Term High-Intensity Interval Training Does Not Improve Body Composition and Cardiovascular Risk Factors in a Sample of Overweight and Obese Men* reported that a short-term HIIT intervention does not necessarily lead to meaningful improvements in cardiovascular risk factors and lipid indices (da Silva et al., 2020). The inconsistency could stem from differences in the duration of the intervention, age and hormonal background, as well as the "team/play-based nature" of futsal, which is usually associated with sustained participation, intensity fluctuations (sprint–recovery), and a specific metabolic load, and could simultaneously influence TG, HDL, and non-HDL lipoproteins (Giovanelli et al., 2025).

The pattern of results from this study suggests that structured recreational futsal, as a small-scale team sport, can simultaneously improve several key atherogenic risk factors in sedentary obese adolescents. Mechanistically, these effects are likely due to a combination of aerobic–anaerobic load, repeated high-intensity intervals, increased fatty acid utilization, and enhanced reverse cholesterol transport efficiency. However, the differences reported in the literature indicate that lipid responses to exercise are highly dependent on participant characteristics (degree of obesity, baseline lipid levels, age/maturation), intervention design (duration, actual intensity, monitoring), and the control of confounding factors such as diet (Sun et al., 2024). Therefore, futsal can be an attractive and sustainable non-pharmacological strategy for improving cardiometabolic health in obese adolescents, especially when implemented in a supervised and progressively designed manner (Racil et al., 2023).

Conclusion

The present study demonstrates that 10 weeks of structured futsal training significantly improved atherogenic indices (CRI-I, CRI-II, AIP, and AC) in inactive obese adolescent boys, indicating a meaningful reduction in cardiovascular risk. The lack of significant changes in the control group confirms that these improvements were attributable to the exercise intervention. Therefore, futsal training may serve as an effective, practical, and non-pharmacological strategy to enhance cardiometabolic health in obese adolescents.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgment

The authors are grateful to the subjects who participated in the study.

ORCID

Berivan Jalal Rashid



<https://orcid.org/>

Naser Rostamzadeh



<https://orcid.org/>

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*Corresponding Author: naserrstamzadeh806@gmail.com.

How to Cite: Jalal Rashid, B., & Rostamzadeh, N. (2026). Effect of 10 weeks of futsal training on Castelli Risk Index I and II, Atherogenic Index Plasma and Atherogenic Coefficient in Inactive Obese Boys, *Journal of New Approaches in Exercise Physiology*, 8(16), 5-23.

DOI: 10.22054/nass.2026.91712.1232.



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