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Relationship of atherogenic index of plasma with exercise, obesity and biochemical parameters

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ABSTRACT

Aims: It is well-known that regular moderate-intensity aerobic exercise has positive effects on various health indicators, including obesity and cardiovascular diseases (CVD) and atherogenic index of plasma (AIP) is defined as a highly sensitive predictor of plasma atherogenicity and cardiovascular risk. Furthermore, it is known that physical activity has a reducing effect on AIP with its ability to decrease visceral fat and its positive impact on blood lipids. Additionally, large-scale AIP screenings are recommended for the early detection of obese individuals and effective intervention. This study aims to determine the relationship between regular exercise and cardiometabolic parameters and obesity based on current data.

Methods: The study involved a total of 126 participants aged 18-65 and it was conducted in the form of file screening, where the medical history reports of all patients were examined, and systemic physical findings were assessed. Fasting blood samples were used to determine the lipid profile. Anthropometric measurements and biochemical parameters of the participants were determined and AIP was calculated using the formula AIP=log10 (TG/HDL-C). Participants were categorized into groups based on their exercise status, BMI, and AIP risks, and the data of the study groups were evaluated statistically.

Results: Participants were divided into two groups based on exercise status, and in the exercise group, body mass index (BMI), body weight, waist circumference, AIP, and triglyceride levels were found to be lower, while high-density lipoprotein (HDL) levels were higher compared to the non-exercise group. In all participants, moderate-intensity exercise was negatively correlated with AIP, body weight, BMI, waist circumference, triglyceride, and low-density lipoprotein (LDL) levels; and positively correlated with HDL levels.

Conclusion: The relationships uncovered in this study among exercise, cardiometabolic parameters, and obesity status are expected to contribute to future research, especially in studies focusing on the impact of exercise on CVD and obesity.

Keywords: Exercise, physical activity, atherogenic index of plasma, obesity

INTRODUCTION

Cardiovascular diseases (CVD) constitute a significant portion of global diseases. Despite advances in medical science and quality healthcare, the prognosis, diagnosis, and treatment of CVD have improved, yet coronary heart disease and stroke continue to be the leading two causes of the global disease burden. According to World Health Organization (WHO) data, in the year 2019, 17.9 million individuals lost their lives due to CVD.[1,2] All these data indicate the necessity of setting new goals for the prevention of CVD.[3]

Atherogenic Index of Plasma (AIP) is defined as a highly sensitive predictor of plasma atherogenicity and cardiovascular risk. It is known that AIP exhibits a strong and positive correlation with the fractional esterification ratio of high-density lipoprotein (HDL) and an inverse correlation with low-density lipoprotein (LDL) particle size.[4] AIP is calculated by the base 10 logarithm of the ratio of triglyceride (TG) concentration to HDL cholesterol (HDL-C) [AIP=log10 (TG/HDL-C)].[5] Additionally, it has been demonstrated that AIP has a stronger correlation with cardiovascular diseases (CVD) compared to other lipid risk scores.[6]

The World Health Organization (WHO) defines obesity as "the abnormal or excessive accumulation of fat that presents a risk to health".[7] In contrast to the perspective that obesity is solely a risk factor for the development of pathology in individuals, the World Obesity Federation characterizes obesity as a chronic, recurrent, and progressive disease.[8] Over the past quarter-century, obesity has raised serious concerns due to its association with the development, progression, impaired

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quality of life, and reduced life expectancy of chronic diseases such as cardiovascular diseases (CVD), diabetes mellitus (DM), cancer, and osteoarthritis. However, the individual risk for the development of obesity-related comorbidities is a complex issue that cannot be explained solely by the degree of adiposity.[9,10]

WHO has reported that physical activity has numerous benefits, including reducing weight, lowering blood pressure, and improving blood lipid and glucose levels.[11] There is a wealth of research suggesting that regular exercise can reduce the risk of developing cardiovascular diseases CVD, including coronary heart disease, stroke, type 2 diabetes mellitus DM, and hypertension. Exercise is recognized as a natural anti-atherogenic agent, and several studies support its role in atheroprotection. Additionally, exercise is known to play a significant mechanical endothelial stimulatory role, serving as a precursor to a series of events that support atheroprotection.[11-13]

While physical activity, especially moderate to vigorous physical activity, has many benefits such as weight loss, lowering blood pressure, and improving blood lipid and glucose levels, studies also indicate its reducing effect on AIP with its ability to decrease visceral fat and its positive impact on blood lipids.[14-17] The detailed mechanism is explained by the effect of exercise on increasing lecithin-cholesterol acyltransferase (LCAT) levels, a key enzyme for the esterification of free cholesterol and its transfer to high-density lipoprotein (HDL) that carries reverse cholesterol. Additionally, exercise may increase lipoprotein lipase (LPL) levels, the primary enzyme responsible for removing circulating triglycerides associated with lipoproteins.[18,19]

Another consideration is that while AIP predicts abnormal weight, there is a limited body of research on the relationship between obesity, excess weight, and AIP. Based on the few studies conducted, it is suggested that AIP is a robust lipid indicator for understanding the risk of obesity. Due to its cost-effectiveness and the simplicity of the testing procedure, large-scale AIP screenings are also recommended for early detection of obese individuals and effective intervention.[20,21] In this study, considering all this information, the aim is to determine the relationship between physical activity status and AIP, biochemical markers, and obesity.

METHODS

Study Design and Population

This study received approval from the Ethics Committee of Clinical Studies at Amasya University Faculty of Medicine (Date: 07.12.2023, Decision No: 2023/135). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. The research was conducted with a total of 126 participants, including 95 females and 31 males, aged between 18 and 65, who applied to Ruhi Tingiz Physical Therapy Rehabilitation Center-Physical Therapy clinic of Amasya University Sabuncuğlu Şerefeddin Training and Research Hospital, Amasya University, from July 15, 2020 to September 15, 2023.

The study was conducted in the form of file screening, where the medical history reports of all patients were examined, and systemic physical findings were assessed. The body-mass index (BMI) values of all patients were calculated using the formula BMI=Weight (kg)/Height (m)^2. AIP values of the patients were calculated using the formula AIP=log10 (TG/HDL-C). Individuals with diabetes, heart failure, acute and chronic kidney failure, chronic liver disease, and acute infectious diseases were excluded from the study.

The laboratory results of individuals who had blood samples taken from the antecubital vein after an overnight fast during routine visits to Amasya University Sabuncuoğlu Şerefeddin Training and Research Hospital between July 15, 2020 and September 15, 2023 were utilized in the study. The laboratuar results of the patients were obtained retrospectively from the patient files.

Statistical Analysis

Continuous data were summarized using mean (μ), standard deviation (Sd), and lower subgroups. Categorical data were expressed as percentages. Student's t-test was employed for binary comparisons of normally distributed data, while the Mann-Whitney U test was used for non-normally distributed data. For normally distributed data with more than two groups, the ANOVA test was utilized, and for non-normally distributed data with more than two groups, the Kruskal-Wallis ANOVA test was applied. Chi-square test was used for the analysis of categorical variables. Statistical analyses were conducted using the SPSS software package, and a significance level of $p<0.05$ was considered.

RESULTS

The comparisons and correlation statistics of the study groups with the study findings are presented in the tables and explanations below.

This study was conducted with a total of 126 participants, comprising 95 females and 31 males. The mean age of the participants was 38.02±9.78, with an age range between 18 and 65. When questioned about engaging in at least 45 minutes of light-to-moderate intensity aerobic exercise (such as brisk walking, swimming, cycling, etc.) at least 3 days a week for the past three months, 45.2% of the participants (57 individuals) reported exercising, while 54.8% (69 individuals) indicated a lack of exercise routine, suggesting a sedentary lifestyle.

AIP, the minimum value was -0.41, the maximum value was 0.89, and the mean value was 0.31±0.27 across all participants. Concerning AIP risk categories, 23% of participants (29 individuals) were classified as low risk, 17.5% (22 individuals) as moderate risk, and 59.5% (75 individuals) as high risk.

When clinical and biochemical findings were evaluated in two groups based on exercise status, it was observed that BMI, body weight, and waist circumference were statistically significantly higher in those who did not exercise compared to those who did exercise ($p<0.001$). In the non-exercise group, triglyceride levels were found to be significantly higher ($p<0.001$), while HDL levels were statistically significantly higher ($p<0.001$) in the exercise group. AIP, a marker for CVD, was significantly higher ($p<0.001$) in the non-exercise group, and the AIP average was classified as high risk (AIP>0.21). There was no statistically significant difference between the groups in terms of total cholesterol and LDL levels ($p>0.05$) (**Table 1**).

There was a statistically significant difference ($p<0.001$) among obesity risk groups based on exercise status and BMI in the groups. The non-exercise group had a higher risk of obesity, while the exercising group showed a lower risk (**Table 2**).

Table 1. Comparison of clinical and biochemical findings according to exercise groups

	Mean±SD			95% CI	
	Non-exercise (n=69)	Exercise (n=57)	p	Minimum	Maximum
Age (year)	40.96±9.83	34.47±8.55	0.0001	3.33	10.21
BMI (kg/m²)	32.23±8.28	25.31±4.62	0.0001	4.48	9.36
Body weight (kg)	84.38±19.65	68.74±12.92	0.0001	9.63	21.64
Waist circumference (cm)	101.42±15.23	82.58±14.91	0.0001	13.49	24.18
AIP	0.47±0.20	0.11±0.21	0.0001	0.28	0.43
Total cholesterol (mg/dl)	187.90±49.08	172.28±40.86	0.0580	-0.51	31.76
Triglyceride (mg/dl)	151.35±71.76	77.35±32.18	0.0001	53.67	94.32
HDL (mg/dl)	46.79±10.28	55.72±11.49	0.0001	-12.77	-5.08
LDL (mg/dl)	113.75±28.74	100.04±31.49	0.0812	3.08	24.35

Mann Whitney U (data follow a non-normal distribution), Student's t-test (data follow a normal distribution), CI: Confidence interval, SD: Standart deviation, BMI: Body mass index, AIP: Atherogenic index of plasma, HDL: High-density lipoprotein, LDL: Low-density lipoprotein

Table 2. Distribution of groups according to exercise status and obesity risk groups

	Normal weight (BMI=18.5-25 kg/m²) (n=43)	Overweight (BMI=25-30 kg/m²) (n=36)	Obese (BMI >30 kg/m²) (n=47)
Non-exercise (n=69) n (%)	11 (15.9%)	22 (31.9%)	36 (52.2%)
Exercise (n=57) n (%)	32 (56.1%)	14 (24.6%)	11 (19.3%)

Chi-Square test (p<0.001), BMI: Body mass index

A statistically significant difference (p<0.001) was observed among AIP risk groups based on exercise status in the groups. In the non-exercise group, the proportion of individuals in the high-risk category for AIP was higher, while in the exercise group, the proportion of individuals in the high-risk category for AIP was lower (Table 3).

Table 3. Distribution of groups according to exercise status and AIP risk groups

	Low risk (AIP<0.11) (n=29)	Intermediate risk (AIP=0.11-0.21) (n=22)	High Risk (AIP>0.21) (n=75)
Non-exercise (n=69) n (%)	0 (0.0%)	10 (14.5%)	59 (85.5%)
Exercise (n=57) n (%)	29 (50.9%)	12 (21.1%)	16 (28.1%)

Chi-Square test (p<0.001), AIP: Atherogenic index of plasma

In all participants, there is a statistically significant negative moderate-level correlation (p<0.001; correlation coefficients are respectively r=-0.654; -0.330; -0.420; -0.451; -0.531; -0.543; -0.405) between engaging in moderate-intensity exercise and AIP, age, body weight, BMI, waist circumference, triglyceride level, and obesity status. There is also a statistically significant negative moderate-level correlation (p=0.012; r=-0.220) between exercise and LDL level. This indicates that as exercise increases, there is a decrease in these biochemical, anthropometric, and demographic parameters. A statistically significant positive moderate-level correlation (p<0.001; r=0.382) is found between exercise and HDL level. However, there is no statistically significant relationship between exercise status and total cholesterol level or the occurrence of metabolic syndrome (p>0.05) (Table 4).

Table 4. Correlation between exercise status and anthropometric and biochemical parameters in all participants

	Correlation Coefficient	p
AIP	-0.654	<0.001
Age (year)	-0.330	<0.001
Body weight (kg)	-0.420	<0.001
BMI (kg/m²)	-0.451	<0.001
Waist circumference (cm)	-0.531	<0.001
Total cholesterol (mg/dl)	-0.170	0.580
LDL (mg/dl)	-0.220	0.012
HDL (mg/dl)	0.382	<0.001
Triglyceride (mg/dl)	-0.543	<0.001
Obesity	-0.405	<0.001

AIP: Atherogenic index of plasma, BMI: Body mass index, LDL: Low-density lipoprotein, HDL: High-density lipoprotein

When clinical and biochemical findings were grouped and evaluated according to AIP risk categories, it was found that body weight, BMI, and waist circumference were statistically significantly different (p<0.01) and increased across all groups as the risk level increased. The LDL level was significantly different (p<0.01) in all risk groups, and as the risk increased, this value increased in all groups. Additionally, the total cholesterol level was statistically significantly higher (p<0.05) in the high risk group compared to the intermediate risk group (Table 5).

DISCUSSION

In individuals with excessive weight and obesity, there is a risk of CVD and many metabolic diseases. However, it is known that especially abdominal obesity and visceral adiposity are stronger indicators in terms of mortality and morbidity risk compared to obesity. There is evidence indicating that moderate-intensity exercise intervention is clinically associated with a significant decrease in waist circumference and abdominal obesity.[22,23]

In this study, when comparing groups, it was found that body weight, BMI, and waist circumference were significantly lower in individuals who engaged in regular, moderate-intensity exercise compared to those who did not exercise.

Table 5. Comparison of clinical and biochemical findings according to AIP risk groups

Mean±SD					
	1 (n=29)	2 (n=22)	3 (n=75)	p	Difference
Age (year)	33.48±8.45	38.73±13.92	39.57±8.31	0.0180	3>1, 2>1
Body weight (kg)	64.26±11.97	71.54±11.58	84.03±19.23	0.0001	3>2, 3>1
BMI (kg/m²)	24.43±4.76	27.55±5.59	31.36±8.22	0.0001	3>2, 3>1
Waist circumference (cm)	78.14±15.73	87.45±17.37	100.20±14.26	0.0001	3>1, 3>2, 2>1
Total cholesterol (mg/dl)	168.17±41.53	168.04±40.65	189.48±47.66	0.0370	3>2, 3>1
LDL (mg/dl)	96.31±31.66	97.50±31.23	114.84±28.27	0.0050	3>2, 3>1

AIP: Atherogenic index of plasma, SD: Standart deviation, BMI: Body-mass index, 1=Low risk (AIP<0.11), 2=Intermediate risk (AIP=0.11-0.21), 3=High risk (AIP>0.21)

These findings are consistent with a systematic review and meta-analysis report that included 25 randomized controlled trials (1686 participants) investigating the impact of aerobic exercise on waist circumference in overweight or obese individuals. According to this report, regular aerobic exercise significantly reduces waist circumference, and this change is associated with changes in visceral fat tissue. The study aimed to determine the relationship between waist circumference, visceral fat accumulation, and body weight changes as a result of aerobic exercise intervention. It also aimed to ascertain whether the reduction in waist circumference due to exercise is managed by components of the aerobic exercise prescription.[24]

Another finding of the study was that engaging in moderate-intensity exercise positively influenced the lipid profile, especially triglyceride, HDL, and LDL levels. This finding is supported by a systematic review and meta-analysis study that examined research conducted between 2007 and 2016 to assess the relationship between exercise, obesity, and lipid profile. The study reported a beneficial effect of exercise intervention on BMI, waist circumference, total cholesterol, triglycerides, LDL, and HDL. It was also noted that the continuity and intensity of exercise correlated with greater and more consistent improvements in adult obesity and lipid profile compared to exercise duration.[25] Consistent with the findings of the present study, a systematic review conducted on animals aimed to provide a general overview of the effects of regular low to moderate-intensity exercise, performed for at least two weeks, on apolipoproteins (Apo A-I, Apo-E), Paraoxonase-1 (PON1), ATP-binding cassette transporters (ABCA1), ABCG1, ABCG4, ABCG5, ABCG8), scavenger receptor class B type I (SR-BI), cholesteryl ester transfer protein (CETP), low-density lipoprotein receptor (LDLr), cholesterol 7 alpha-hydroxylase (CYP7A1), and Niemann-Pick C1-like 1 (NPC1L1). The review revealed that in studies predominantly focused on moderate-intensity aerobic exercise, exercise had a positive effect on atherosclerosis and reduced the risk of CVD, which is a primary concern of contemporary health systems. It emphasized that various mechanisms, including the modification of reverse cholesterol transport (RCTr) process elements, mediate the positive effects of exercise on CVD. The review highlighted that several mechanisms, involving PPAR, LXR, FXR, and PXR, along with various hormones and cytokines, influence RCTr elements, but the mechanism of RCTr changes associated with exercise remains unclear.[26]

There is ample evidence from various studies supporting the idea that aerobic exercise partially lowers serum TG and LDL levels while increasing HDL levels, thereby reducing the risk of coronary heart disease (CHD) associated with high or abnormal lipid and/or lipoprotein levels. Additionally, exercise has an impact on HDL maturation and composition, influencing reverse cholesterol transport from peripheral cells to the liver. This process contributes to the prevention of atherosclerosis, improvement of cardiac lipid metabolism, and thus demonstrates a protective effect against CVD.[27] It is well-established that regular physical activity and exercise have both direct and indirect physiological adaptations, as well as numerous pleiotropic benefits on cardiovascular health. Higher levels of physical activity, exercise, and cardiorespiratory fitness (CRF) are associated with a reduced risk of CVD, including myocardial infarction and mortality related to CVD and all causes.[28] In a meta-analysis study involving thirty-eight articles encompassing a total of 2089 CVD patients, it was indicated that aerobic exercise significantly reduces aortic systolic pressure (ASP), improves carotid-femoral pulse wave velocity, cardiac output, and left ventricular ejection fraction. Aerobic exercise intervention in CVD patients has substantially enhanced central arterial stiffness and cardiac function. These findings suggest that a well-designed regimen intervention could optimize the beneficial effects of exercise and provide guidance for those involved in cardiovascular rehabilitation of CVD patients.[29] A review aimed at summarizing recent findings on the multiple benefits of exercise on CVD highlighted that physical activity could enhance insulin sensitivity, alleviate plasma dyslipidemia, normalize high blood pressure, reduce blood viscosity, stimulate endothelial nitric oxide production, and enhance leptin sensitivity to protect the heart and vessels. The same review emphasized the general exercise intensity recommended by the American Heart Association for preventing CVD, highlighting 30 minutes of moderate-intensity exercise five times a week. However, it was noted that even the easiest activity is better than a completely sedentary lifestyle. Furthermore, considering individual differences in physical fitness, it was emphasized that a standardized exercise regimen might not provide a complete treatment for everyone, and thus, exercise should be personalized.[30]

In the current study, the average AIP of the exercise group was significantly lower than that of the non-exercise group. Non-exercisers were found to have moderate and high-risk AIP classifications, and there was a statistically significant negative correlation between exercise status and AIP at a moderate level. These findings align with a cross-sectional study involving 27,827 middle-aged Chinese men, where a correlation between moderate-intensity aerobic exercise duration and AIP was determined. In the PA1 (non-exercise), PA2 (occasional exercise), and PA3 (frequent exercise) groups, AIP levels were significantly higher in PA1 and PA2 groups compared to the PA3 group. Additionally, the percentage of the population at high risk for atherosclerosis (AIP ≥0.21) was significantly lower in the PA3 group compared to the PA1 and PA2 groups. It was suggested that engaging in at least 90 minutes of moderate-intensity aerobic exercise per week was associated with a reduction in AIP among middle-aged Chinese men.[31] In a study involving 2,701 adults investigating the relationship between moderate to vigorous physical activity, dietary behavior, and AIP, engaging in regular physical activity despite unhealthy dietary behavior was associated with a reduced likelihood of having a high AIP. The same study highlighted that visceral fat mediated the relationship between physical activity and AIP.[32] Similarly, in another study aimed at investigating the effects of 8 weeks of aerobic exercise on anthropometric indices, AIP, and some cardiovascular risk factors in inactive men, participants who underwent aerobic exercise at 70% of their maximum heart rate were evaluated with blood samples taken before and after exercise. The results indicated a significant decrease in body fat percentage, cholesterol, LDL/HDL ratio, TG/HDL ratio, and apo-β after 8 weeks of aerobic exercise. Additionally, VO2max and HDL showed a significant increase after 8 weeks of aerobic activity, suggesting that an increase in physical activity could reduce the risk of cardiovascular disease.[33] When examining a study that investigated the relationship between AIP and acute aerobic exercise in healthy young men aged 18-25, blood samples were taken before, immediately after, and 15 minutes after exercise to assess biochemical parameters. The results revealed a statistically significant increase in average HDL values at different stages of aerobic exercise, along with a significant decrease in triglycerides, AIP, and weight averages at different stages of exercise. The study suggested that exercise has the potential to reduce CVD risk in sedentary, non-obese young men who aim to maintain a physically active lifestyle. Moreover, the correlation observed between different stages of aerobic exercise and AIP indicated the significant role of short-term aerobic exercise in mitigating CVD risk.[34]

CONCLUSION

CVD constitutes a significant portion of the global disease burden, and AIP is commonly used as a sensitive and practical criterion for assessing CVD risk. Obesity, like many chronic diseases, is a substantial risk factor for CVD. However, regular exercise plays a crucial role in both preventing obesity and supporting atheroprotection. This study further demonstrated that regular moderate-intensity exercise is directly associated with body weight, BMI, waist circumference, and obesity status. Additionally, it revealed correlations between regular exercise and key cardiometabolic parameters such as LDL, triglyceride levels, and AIP. The findings of this study, which align with current literature, are expected to shed light on future research exploring the relationships between exercise, obesity, and AIP.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Amasya University Non-invasive Clinical Researches Ethics Committee (Date: 07.12.2023, Decision No: 2023/135).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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Author Contributions

All of the authors declare that they have all participated in the design, execution and analysis of the paper and that they have approved the final version.

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