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EFFECTIVENESS OF PHYSICAL EXERCISE IN MANAGING COMPONENTS OF METABOLIC SYNDROME IN OBESE POPULATIONS: A SYSTEMATIC REVIEW

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ABSTRACT
Obesity is one of the main contributing factors to metabolic syndrome, which results in an increased risk of chronic diseases such as diabetes mellitus, cardiovascular disease, and other metabolic dysfunctions. Physical exercise has long been recognized as a potential nonpharmacological strategy in reducing metabolic risk factors, but the effectiveness of various types of exercise in managing metabolic syndrome still needs to be further reviewed. This study aims to evaluate the effectiveness of physical activity in managing components of metabolic syndrome in an obese population. Using the PRISMA method of literature searches through Pubmed, Ebsco, Scopus and Wiley databases by using specific word combinations to obtain suitable articles. Inclusion criteria included English language articles published in the last five years (2019-2024), randomized controlled trial type, and discussing physical exercise interventions in obese populations. Of the 893 articles retrieved, 7 were reviewed. Studies show that physical exercise significantly reduced risk components of metabolic syndrome such as blood sugar, insulin, HOMA-IR, visceral fat and improved VO 2 max and quality of life. However, long term success was strongly influenced by the level of adherence to the exercise program. Physical exercise in an effective and safe intervention in reducing the risk of metabolic syndrome in obese individuals.

Keywords: metabolic syndrome; obesity; physical exercis

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INTRODUCTION

Obesity has emerged as a major public health challenge in the 21st century, contributing to the rising prevalence of metabolic syndrome (MetS) (Thomaz et al., 2024). According to WHO data from 2022, 2.5 billion adults worldwide are overweight, and among them, 890 million live with obesity. Several factors may lead to obesity, including a sedentary lifestyle, overnutrition, socioeconomic status, environmental influences, and genetic predisposition (Yang et al., 2022). Obesity, both directly and indirectly, contributes to the development of various chronic diseases, such as chronic kidney disease, cardiovascular disease, non-alcoholic fatty liver disease (NAFLD), cancer, and diabetes mellitus (Ward et al., 2019; Zhang et al., 2021). Inflammation, insulin resistance, and metabolic dysfunction caused by obesity significantly impact the morbidity and mortality associated with these chronic conditions (Yang et al., 2022).To address this issue, interventions focused on weight loss through lifestyle changes—including a balanced diet and increased physical activity—are essential in managing this condition (Sandouk et al., 2017). Physical exercise has long been recognized as an effective non-pharmacological intervention to improve metabolic health. Various forms of physical activity, such as aerobic exercise, resistance training, and interval training, have the potential to reduce waist circumference, enhance insulin sensitivity, lower triglyceride levels, and regulate blood pressure (Roberts et al., 2013). Increased physical activity induces structural changes in muscle tissue, increases the number of mitochondria in muscle fibers, promotes the secretion of metabolically beneficial hormones like irisin,

reverses muscle insulin resistance, and reduces postprandial hepatic lipogenesis (Saklayen et al., 2018).

Beyond its direct benefits on metabolic health, physical activity also has positive effects on mental well-being. Studies have shown that physical exercise can reduce levels of stress, anxiety, and depression, which are commonly observed among individuals with obesity (Mahindru et al., 2023). These psychological benefits can support the sustainability of lifestyle changes, including healthier eating habits and more effective weight management (Staiano et al., 2016). However, the overall effectiveness of physical activity in managing all components of metabolic syndrome still requires further review within the broader context of scientific evidence.This study aims to evaluate the effectiveness of physical exercise in managing components of metabolic syndrome among the obese population. It is expected that the results of this review will provide guidance for healthcare practitioners in designing evidence-based exercise programs for managing obese patients with metabolic syndrome in clinical practice

METHOD

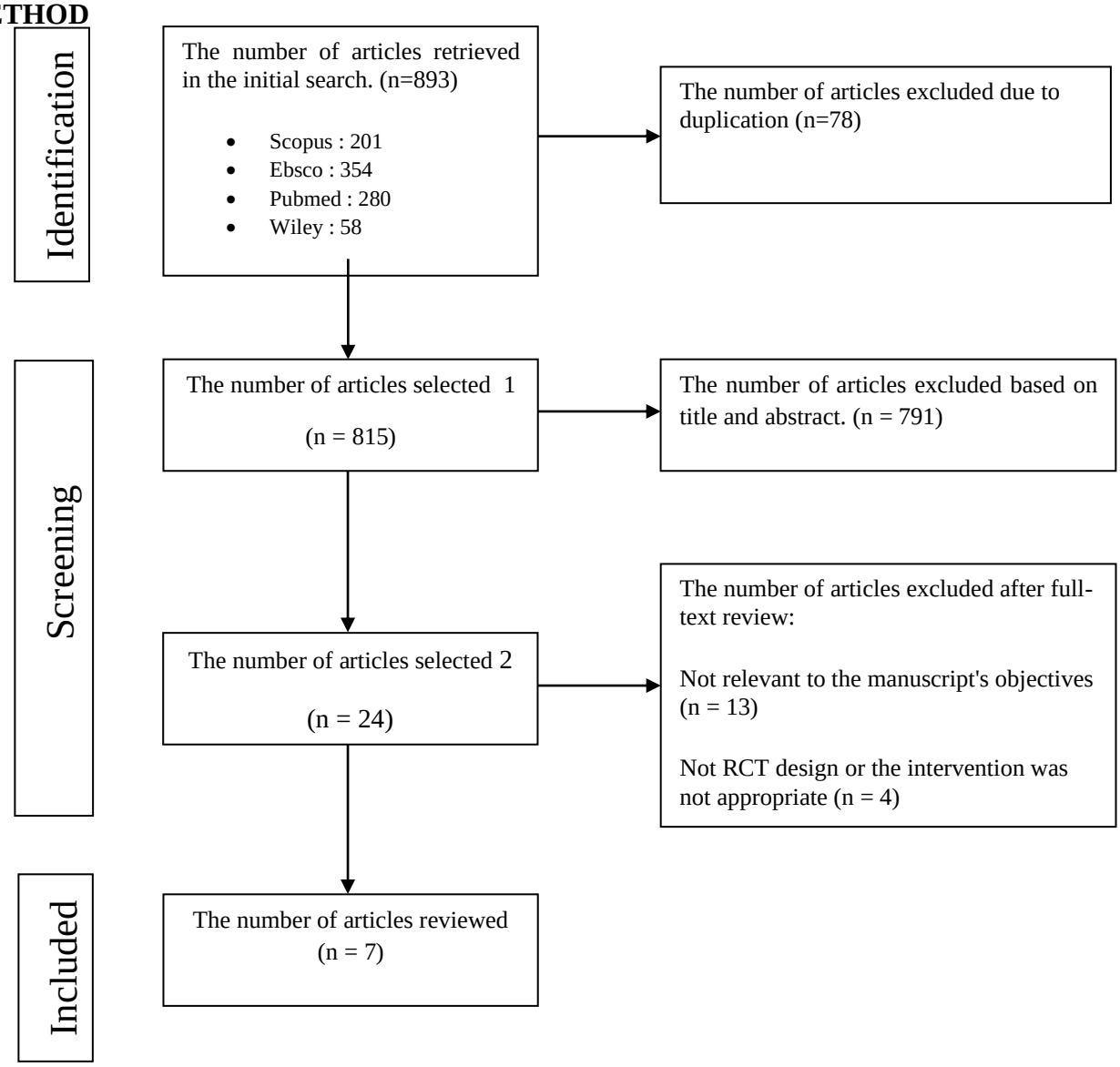

Diagram 1. Prisma Diagram

This systematic review employs the PRISMA method, using databases such as Pubmed, Ebsco, Scopus, and Wiley for literature search. Boolean operators (AND, OR, NOT) were used with the following search terms: (obesity OR obese AND physical exercise OR exercise OR fitness OR AND metabolic syndrome OR metabolic disease). The PRISMA statement outlines four steps in the search

process: identification, screening, eligibility, and inclusion. Inclusion criteria include articles with an abstract and full text, published in English within the last five years (2019-2024), focusing on physical exercise and components of metabolic syndrome in the obese population, and with a randomized controlled trial design. Exclusion criteria are articles that are not accessible as full texts, books, literature reviews, theses, and studies not addressing physical activity and metabolic syndrome in obese populations. The literature search started in November 2024. A total of 893 articles were identified during the search process, from which 7 articles were selected for in-depth analysis. In the final screening stage, studies underwent quality assessment using the JBI critical appraisal tool for randomized controlled trials to assess the risk of bias, including 13 questions covering randomization to statistical analysis.

RESULT

Table 1.
Results Search Literature

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
Cicek et al., 2024	The aim of this study was to investigate the effects of two different exercise programs, aerobic exercise (AE) and high-intensity interval training (HIIT), on plasma pentraxin 3 (PTX3) levels in overweight and obese women.	• Participants were recruited through posters, word of mouth, social media, and emails around the academic community of Hitit University in Türkiye. • Inclusion criteria: women aged 20 to 40 years with a BMI between 18.5 and 35 kg/m², who were sedentary before the study (n=45) • Exclusion criteria: experiencing menopause, having a smoking habit, metabolic or cardiovascular disease, arrhythmia, heart failure,	RCT	• The study involved 45 women aged between 20 and 40 years, categorized into three groups: a control group of normal-weight women and two exercise groups (aerobic exercise (AE) and high-intensity interval training (HIIT)) of overweight and obese women. • Participants undergo training for 12 weeks, with sessions held three times a week. The AE session lasted 50 minutes, including a warm-up and aerobic step exercises, while HIIT involved intervals of	• This study found that aerobic exercise (AE) and high-intensity interval training (HIIT) significantly increased plasma levels of Pentraxin 3 (PTX3) by 47.53% and 50.21%, respectively, after 12 weeks of training ($p < 0.01$). • Improvements were also noted in glucose, insulin, HOMA-IR, LDL-C, and hsCRP levels, while HDL-C and VO2max increased significantly in both exercise groups ($p < 0.05$; $p < 0.01$) • No significant differences were found between the two types of exercise regarding lipid parameters.	• The study sample size was limited to 45 participants, which may affect the generalizability of the results to a wider population. • Participants were all sedentary women aged between 20 and 40 years, potentially limiting the applicability of the findings to other demographics. • Future studies can be conducted with a more diverse pool of participants and a longer follow-up duration to evaluate the long-term impact of aerobic and HIIT training on metabolic health.

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
		hypertension, diabetes, orthopedic limitations, exercising regularly during the last 6 months, and having a BMI below 18.5 and above 34.9 kg/m2		high-intensity running and rest periods.		
Waters et al., 2022	The aim of this study was to determine the effectiveness of different exercise modalities—aerobic (AEX), resistance (REX), and combination (COMB)—in reducing intramuscular adipose tissue (IMAT) and visceral adipose tissue (VAT) in older adults with obesity during a weight loss program.	• Volunteers were recruited from Albuquerque, New Mexico through advertisements, and informed consent was obtained from each participant (n=160). • The study involved adults aged 65 years and older, who were classified as obese with a body mass index of 30 kg/m² or higher. • Exclusion criteria: individuals with severe cardiopulmonary disease, musculoskeletal or neuromuscular disorders, cognitive impairment, or those taking medications that affect	RCT	• This study used a randomized controlled trial (RCT) design to compare the effects of aerobic exercise (AEX), resistance exercise (REX), and a combination of the two (COMB) on body composition and physical function in older adults with obesity during a weight loss program. • Participants were grouped by sex and assigned to one of four groups: control (CON), AEX, REX, or COMB. • Each exercise group followed a weight management program, attending exercise sessions	• This study found that weight loss combined with aerobic and resistance exercise (COMB) was most effective in reducing intermuscular adipose tissue (IMAT) and visceral adipose tissue (VAT) in older adults with obesity. • The insulin sensitivity index (ISI) increased significantly more in the COMB group (86%) than in AEX (50%) and REX (39%) • Physical function, as measured by the Modified Physical Performance Test (PPT), also showed greater improvement in the COMB group.	• The sample size may not be large enough to examine potential sex differences in regional body composition changes. Future studies could be conducted in larger, more diverse populations to explore these differences.

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
		body composition.		three times per week for 60–90 minutes, while the control group received diet education. • Assessments were conducted at baseline and after six months, measuring intermuscular and visceral fat, insulin sensitivity, and physical performance.		
Son et al., 2021	The aim of this study was to examine the effects of a resistance band exercise program on various parameters of metabolic syndrome (MetS) in obese postmenopausal women.	• This study involved a total of 35 postmenopausal women specifically selected for this study who were randomly assigned to a control group (CON, n = 17) or a resistance band training group (EX, n = 18).	RCT	• This study used a randomized controlled trial design, assigning 35 obese postmenopausal women to a control group (CON, n = 17) or a resistance band training group (EX, n = 18) for 12 weeks. • The EX group participated in a supervised resistance band exercise program three times a week, including a warm-up, main exercise session, and cool-down. • Resistance band training is done for 60 minutes	• A resistance band training program resulted in significant improvements in multiple components of metabolic syndrome among obese postmenopausal women. Blood glucose levels decreased by an average of 4.5 mg/dL, insulin levels by 1.3 μU/mL, and HOMA-IR by 0.6 after the intervention. • In addition, triglyceride and low-density lipoprotein cholesterol levels decreased by 9.4 mg/dl and 10.8 mg/dl, respectively. • Systolic blood pressure decreased by 3.4 mmHg, while lean	• This study has limitations, including a relatively small sample size, which may affect the generalizability of the results to a broader population. • The short study duration (12 weeks) may not capture the long-term effects of resistance band training on metabolic syndrome. • Future research should consider longer study durations to better understand the sustained benefits of resistance band training. • In addition, controlling participants' daily activities can provide a more accurate assessment of the impact of the

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
				with 10 minutes of warming up and cooling down and 40 minutes of main training. • Measurements of blood glucose, insulin, HOMA-IR, blood lipid profile, anthropometry, and blood pressure were performed at baseline and after the intervention.	body mass increased by 0.7 kg and high-density lipoprotein cholesterol increased by 5.1 mg/dl. • These findings suggest that resistance band training is an effective intervention to improve metabolic health in this population.	exercise program.
Duan et al., 2024	The aim of this study was to investigate the effects of a 12-week resistance training (RT) and aerobic training (AT) program on FGF-21 levels and other physiological variables in obese men.	• The study involved a total of 36 obese men. • Participants were matched based on their FGF-1 levels and randomly assigned to three groups: resistance exercise (RT, n = 12), aerobic exercise (AT, n = 12), and an inactive control group (n = 12). • Inclusion and exclusion criteria: 1. Diagnosed with T2DM for at least four years 2. Having a sedentary lifestyle with an age	RCT	This study used a randomized controlled trial design to assess the effects of resistance training (RT) and aerobic training (AT) on FGF-21 levels and related physiological variables in obese men with type 2 diabetes mellitus. Thirty-six sedentary obese diabetic men aged 40 to 45 years were matched on FGF-21 levels and randomly assigned to RT, AT, or an inactive control group. Both training interventions were conducted three times a	• This study found that resistance training (RT) and aerobic training (AT) significantly increased FGF-21 levels and various biochemical variables associated with type 2 diabetes mellitus (T2DM) in obese men. • RT showed greater improvements in glucose metabolism, hormonal changes, maximal strength, and FGF-21 levels compared to AT. • In contrast, AT was more effective in improving lipid profiles and aerobic capacity. • Both training modalities	• This study did not address the potential for long-term adherence to resistance training (RT) and aerobic training (AT) among participants, which may impact the sustainability of health benefits. • The lack of diversity in the sample, as it only included sedentary obese men aged 40 to 45 years, limits the generalizability of the findings. • Future research should consider including more diverse populations and longer follow-up periods to assess the long-term effects of both training modalities. • Additionally, exploring

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
		between 40 and 45 years 3. HbA1c level of 6.5% or higher with current blood sugar levels ranging from 150 to 200 mg/dL 4. Body mass index greater than 30 kg/m2 5. Have no history of musculoskeletal injuries or orthopedic problems that affect exercise efficiency.		week for 12 weeks, with each session lasting 60 to 70 minutes, including warm-up and cool-down periods. Blood samples were collected before and after the intervention to measure various biochemical markers, including FGF-21, glucose, and lipid profile.	resulted in significant decreases in fasting blood sugar, HbA1c, insulin, and HOMA-IR, indicating improved insulin sensitivity.[2]	psychological factors that influence adherence to exercise programs may provide valuable insights for improving intervention strategies.
Reljic et al., 2021	The aim of this study was to investigate the effects of two time-saving training protocols, high-intensity interval training (HIIT) and moderate-intensity interval training (MIIT), in obese patients with metabolic syndrome (MetS) over a 12-week period.	• A total of 117 participants were recruited through local newspaper advertisements, with inclusion criteria including age 18 years, obesity (BMI ≥ 30 kg/m²), increased waist circumference (≥ 88 cm for women, ≥ 102 cm for men), and at least two additional cardiometabolic abnormalities such as hypertension,	RCT	The study used a 12-week randomized controlled trial design, with participants divided into an inactive control group that received nutritional counseling or an exercise group that performed high-intensity interval training (HIIT) or moderate-intensity interval training (MIIT) in addition to nutritional counseling. The HIIT protocol consisted of a 2-minute warm-up	• This study found that high-intensity interval training (HIIT) and moderate-intensity interval training (MIIT) led to significant improvements in maximal oxygen uptake (VO2max) and metabolic syndrome (MetS) z-score in obese metabolic syndrome patients, with HIIT showing superior results. The HIIT group experienced an increase in VO2max of 3.1 mL/kg/min and a reduction in MetS z-score of 1.8 units, while the MIIT	• A limitation of this study is the short intervention period (12 weeks), which raises questions about the long-term effectiveness and adherence to very low-volume HIIT and MIIT in an obese population. • This study was conducted in a well-controlled setting with careful supervision of all exercise sessions. Thus, further research is needed to clarify whether obese individuals with increased cardiometabolic risk would be able and/or willing to follow existing exercise

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
		dyslipidemia, and hyperglycemia. • Exclusion criteria included a clinical diagnosis of heart disease, cancer, severe orthopedic conditions, or other major health problems that could hinder safe sports participation, as well as pregnancy.		phase, 5 1-minute intervals at 80-95% of HRmax interspersed with 1 minute of low-intensity recovery and 3 minutes of cool-down (total session time: 14 minutes). The minimum intensity to be achieved was progressively increased every 4 weeks during the intervention with HRmax, respectively (weeks 1-4: 80-85%, weeks 5-8: 85-90%, and weeks 9-12: 90-95%).). The MIIT protocol was designed identically (i.e. 2-minute warm-up, 5 1-minute intervals interspersed with 1 minute of low-intensity recovery and 3 minutes of cool-down phase; total session time: 14 minutes), with the exception that participants were required to achieve exercise intensities in the range of 65–80% HRmax during all sessions.	group showed an increase of 1.2 mL/kg/min and a reduction of 1.2 units, respectively. Both exercise groups also reported significant improvements in quality of life (QoL) compared to the control group.	protocols without close supervision.

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
				The primary outcome was maximal oxygen uptake (VO2max), while secondary outcomes included metabolic syndrome z-score, body composition, and quality of life.		
Lehmann et al., 2024	The aim of this study was to compare the effectiveness of strength training versus resistance training in reducing visceral fat mass in individuals with obesity over a 24-month period.	• The study included 239 participants with abdominal obesity, aged 18–60 years, who had a body mass index (BMI) of 35 kg/m² or higher and a waist circumference of 102 cm for men and 88 cm for women. • The mean age of participants was 44 years, with 74% women and a mean BMI of 37 kg/m².	RCT	Participants engage in training sessions two to three times a week, each lasting 60 minutes, in addition to standard nutritional counseling. The primary outcome was changes in abdominal visceral fat, measured by magnetic resonance imaging (MRI) after 12 months. Secondary outcomes included assessment of other fat measures, quality of life, energy expenditure, and glucose metabolism. Data on nutritional intake and lifestyle habits were collected using self-reported food frequency questionnaires at several	• There was no significant difference in decreasing visceral adipose tissue (VAT) between strength and endurance training after 12 and 24 months (p = .13) • A trend towards reduction in visceral adipose volume was observed only in participants with good compliance to the training program. • Both forms of exercise cause moderate loss of abdominal subcutaneous adipose tissue volume and body fat. • The primary outcome measure was VAT assessed by MRI, with secondary outcomes being other fat measures and metabolic parameters.	• This study faced significant limitations with a retention rate of approximately 50%, indicating challenges in participant adherence to exercise interventions, which is a common barrier in lifestyle modification for obesity management. • Factors contributing to low compliance include lack of time, health limitations, and negative perceptions of exercise. • To improve compliance, this study suggests implementing more flexible training schedules and personalized exercise programs that align with individual preferences and lifestyle. • Additionally, increasing motivation through regular feedback and

Writer, Year	Objective	Sample	Method Study	Intervention	Results	Information
				time points.	• Overall, both types of training showed similar effects on body composition and metabolic health.	support can help participants maintain engagement in the program.
Kim et al., 2019	The aim of this study was to examine the effects of a 12-week combined resistance and aerobic exercise program on cardiometabolic biomarkers and red blood cell (RBC) hemorheological function in obese older men.	• The study involved 20 older, obese Korean men with a mean age of 68.8 ± 0.9 years, who had not performed any exercise for the previous six months. • Participants were selected based on a body mass index (BMI) between 25 and 30. • Exclusion criteria included uncontrolled chronic disease, recent lower extremity fracture, and severe cognitive impairment.	RCT	The exercise intervention group (EXP) participated in a 12-week combined resistance and aerobic exercise program, three times a week, at Kyunghee University in South Korea, while the control group (CON) maintained their regular lifestyle. EXP subjects performed the following three types of combined exercise interventions for 90–120 minutes: elastic resistance training, aerobic exercise on a treadmill, and aerobic exercise on a bicycle.	• The study found that the experimental group (EXP) significantly reduced body weight, fat mass, and percent body fat during the 12-week intervention, while the control group (CON) showed a decrease in fat-free mass and an increase in fat mass and percent body fat. • Insulin levels increased significantly in the CON group, while the EXP group experienced decreased insulin and HOMA-IR levels. • Overall, the combination of resistance training and aerobic exercise had positive effects on cardiometabolic biomarkers and body composition in obese older men.	• The small sample size may limit the generalizability of the findings regarding the effects of exercise intervention on cardiometabolic biomarkers and red blood cell hemorheological parameters in older men. • Subjects' food intake and physical activity were not monitored, which may affect the results and should be considered in future studies.

Table 2.
Synthesis of results based on interventions carried out

Intervention	Ciceket al., 2024	Waters, et et al.,2022	Son, et et al., 2021	Duan, et et al.,2024	Reljic, et et al., 2021	Lehmann, et et al., 2024	Kim, et al., 2019
Aerobic	√	√		√			
High-intensity interval training	√				√		
Moderate intensity interval training					√		
Resistance Exercise		√	√	√			
Aerobic + Resistance Exercise		√					√
Strength						√	
Endurance						√	

Table 2.
Synthesis of results based on the outcomes obtained

Outcome	Ciceket al., 2024	Waters, et et al.,2022	Son, et et al., 2021	Duan, et et al.,2024	Reljic, et et al., 2021	Lehmann, et et al., 2024	Kim, et al., 2019
Body Weight (kg)	√	√			√	√	√
BMI (kg/m2)	√		√		√		
Fat Mass (kg)	√		√		√	√	√
Abdominal VAT		√					
Waist Circumference (cm)	√		√		√		
Hip Circumference (cm)	√						
VO2 max (mL/kg/min)	√				√		√
HOMA-IR (Unit)	√		√	√			√
Insulin sensitivity index		√				√	
Glucose (mg/dL)	√	√	√		X	√	X
Insulin (U/mL)	√	√	√	√			√
LDL-C (mg/dL)	√		√	√	X		
HDL-C (mg/dL)	√		√	√	X		
Total Cholesterol (mg/dL)	X			√	X		
Triglycerides	X		√	√	X		
Systolic Blood Pressure			√		√		
Diastolic Blood Pressure			X		√		
Mean Arterial Blood Pressure					√		

DISCUSSION

In this systematic review, a literature search was conducted using several databases. The primary focus was on randomized controlled trials (RCTs) that investigated the impact of physical exercise on metabolic syndrome in obese populations. From the selection process, seven articles were identified that met the inclusion criteria. These articles discussed various exercise approaches, such as aerobic training, resistance training, a combination of both, and high-intensity interval training (HIIT), involving 652 obese adults.The study by Cicek et al. (2024) showed that both HIIT and aerobic exercise had a positive effect on improving aerobic capacity (VO2max), lowering blood pressure, and improving blood lipid profiles.

Impressively, these results were achieved within just 12 weeks of intervention. These findings indicate that although the training duration was relatively short, the results can be significant when the right intensity and method are used.On the other hand, a combination of aerobic and resistance training demonstrated a more comprehensive metabolic effect. Waters et al. (2022) found that this combined exercise type produced the most significant improvements in insulin sensitivity and reductions in visceral fat compared to aerobic or resistance training alone. Similar findings were reported by Kim et al. (2019), who observed improvements in metabolic biomarkers and blood hemorheology following combined training in obese elderly men. Additionally, the study found that this training combination improved participants' quality of life. In other words, the combined training approach can be considered a standard lifestyle intervention, especially for individuals with obesity.

Resistance training alone also showed positive outcomes, particularly in specific groups such as postmenopausal women. Son et al. (2021) demonstrated that resistance training using resistance bands significantly reduced blood glucose and lipid profiles. Meanwhile, Duan et al. (2024) found that resistance training increased levels of FGF-21, which plays a role in metabolic regulation. Notably, this effectiveness was achieved without dietary or pharmacological interventions. This highlights that resistance-based exercise interventions can serve as a standalone approach for metabolic improvement.In terms of training intensity, Reljic et al. (2021) compared HIIT and moderate-intensity interval training (MIIT) in a short but structured program. The results showed that HIIT was superior in reducing metabolic syndrome scores and improving VO2max. Beyond physiological impacts, benefits were also seen in improved quality of life among participants. These findings suggest that even low-volume exercise can be effective if performed at high intensity. Nevertheless, it is important to ensure safety with this type of training, especially for obese individuals with comorbid conditions.

However, regardless of how effective physical interventions may be, the biggest challenge remains participant adherence to the exercise program. Lehmann et al. (2024) emphasized that the success of a long-term 24-month program largely depends on active participant engagement. The study emphasized that the duration of the intervention alone is not enough if participants do not consistently follow the program. Common barriers include lack of time, low motivation, and negative perceptions toward exercise. Therefore, it is important for healthcare providers to design supportive strategies such as continuous education and social support to help maintain participant motivation.Although the outcomes from various studies in this review present a positive outlook on the effectiveness of physical exercise in addressing metabolic syndrome, there are several important limitations to consider. One major limitation is the variation in types of exercise used across studies. Some used aerobic training, while others applied HIIT, resistance training, or combinations thereof. These differing approaches make it difficult to draw definitive conclusions about which type of exercise is most effective in treating metabolic syndrome. Additionally, the sample characteristics also varied widely in terms of age, sex, health conditions, and number of participants. These differences limit the generalizability of the findings to broader populations.Therefore, while this review indicates that physical exercise is a promising non-pharmacological intervention, conclusions regarding the specific effectiveness of each exercise type should not be generalized. Further research with more standardized designs and targeted populations is needed to strengthen these findings and produce more specific and applicable exercise guidelines.

CONCLUSION

This review demonstrates that physical exercise is effective in reducing risk components of metabolic syndrome in obese populations. However, long-term effectiveness depends heavily on participant adherence. Therefore, exercise-based interventions must be tailored to

individual needs, taking into account their preferences and limitations. Further research is necessary to develop more specific and practical exercise guidelines.

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