THE EFFECTS OF COMBINED PHYSICAL TRAINING ON INSULIN RESISTANCE AND MUSCLE FUNCTION IN METABOLIC SYNDROME: A SYSTEMATIC REVIEW

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ABSTRACT

Background and objectives: People with metabolic syndrome (MetS) may benefit from regular exercise. Here, we investigated the effects of aerobic, resistance, and

combined (aerobic + resistance) exercise on insulin resistance and muscle function in people with MetS.

Data searches: MEDLINE via PubMed, Cochrane-CENTR, SPORTDiscus, and EMBASE.

Study choice: The efficacy of exercise training in reducing at least one of the following outcomes was evaluated: HOMA, fasting glucose, and fasting insulin in adults with MetS. Two independent reviewers extracted data and evaluated the quality of the studies included. The results of the exercise training group and control group were compared based on random effects**.**

Results: Seven of the 1671 articles retrieved were included in the review. In the studies, the irisin-1 levels increased in both aerobic and resistance exercise groups, and the nesfatin-1 level increased in all groups. Compared with the control, three groups showed positive changes in anthropometric indices, lipid profile, and insulin resistance. Both aerobic interval training (AIT) and strength training (ST) reduced the total body fat, fat mass, and waist circumference of participants. AIT increased the VO_{2max} by 11%, and ST increased the maximum leg strength by 45%. The Ln HOMA-IR, carnosine, or musclin levels did not differ between the high-intensity interval training (HIIT) and moderate-intensity continuous training groups. HIIT + resistance training reduced the body weight, body mass index, waist circumference, and fasting glycaemia of participants. Meanwhile, HIIT + HIIT improved the triglyceride levels and mean blood pressure. Both therapies caused a non-significant decrease in the musclin levels. Exercise training also reduced insulin resistance and improved cell function.

Our findings show that combined training exhibits greater efficacy in controlling MetS parameters than the other forms of physical activity studied. This modality can be applied widely to prevent MetS and improve MetS parameters in affected individuals.

KEY WORDS Metabolic Syndrome Aerobic Exercise Resistance Exercise Insulin resistance Muscle function

INTRODUCTION

Metabolic syndrome (MetS) has been linked to hypertension, a sedentary lifestyle, the intake of foods rich in refined fats and carbohydrates, insulin resistance, low high-density lipoprotein (HDL) cholesterol levels, and a few other risk factors (1, 2). The recurrence of MetS worldwide can be confirmed based solely on the identification of specific risk factors in individuals, and currently, MetS is considered a global health concern. According to data provided by the Centers for Disease Control and Prevention, adults with MetS account for one-third of the population in the US. In China, the prevalence of MetS cases reached 15.5% of the afflicted population in the same year, with 15.5% of the affected population in the same year (3).

The disease and its effects are well understood, and regular physical activity is widely accepted to be essential for the prevention and treatment of MetS, as it improves and regulates the factors that affect MetS development, such as lipid profile, blood

glucose and insulin levels, blood pressure, anthropometric parameters, and muscle mass, and thus lowers the risk of cardiovascular disease and improves metabolic control.

With the growing popularity of various physical training regimens, the training regimen most effective in regulating MetS is difficult to determine. As a result, even under identical training conditions (aerobic training (AT), strength training (ST), or their combination), samples show variations in results owing to their unique metabolic characteristics evaluated through physical exercise (Moreno-Cabaa et al., 2021; 1, 4).

AT and ST performed concurrently do not alter muscle hypertrophy or maximal strength development but attenuate explosive strength gains. The attenuation of explosive strength was found to be more pronounced when concurrent training was performed in the same session ($P = 0.043$) than in sessions separated by at least 3 h ($P > 0.05$). These results appeared to be independent of the type of AT, frequency of concurrent training, training status, and mean age of individuals (5).

Based on the abovementioned findings, in this review, we evaluate data from randomised clinical trials and describe the effects of physical exercise on insulin resistance in people with MetS by developing an experimental methodology that compares AT and resistance training (RT) regimens and grouping results that indicate alterations in MetS.

RESEARCH DESIGN AND METHODS

Literature Search

The study comprised the following stages: (1) delimitation of the theme and construction of the guide question; (2) survey of publications in the selected databases; (3) classification and analysis of the information retrieved; (4) analysis of the selected studies; (5) inclusion of the studies, critical analysis of the findings, and synthesis of the literature review.

The PICO strategy, which stands for 'Problem, Intervention, Comparison, and Outcomes,' was used for the development of the research question. The PICO strategy was divided into four parts: (P) 'metabolic syndrome in individuals older than 18 years'; (I) 'influence of combined training on insulin resistance'; (C) 'difference between aerobic and resistance physical activity'; and (O) 'to identify impacts of different for MetS of physical activity on individuals with metabolic syndrome'. Through the study, we intended to address the following key question: "What effects do aerobic physical activity and resistance physical activity exert on insulin resistance in patients with MetS?"

We conducted a systematic literature search using the MEDLINE computerised database, selecting articles published from the inception of the platform to November 2021, using the following medical subject headings (MeSH terms):

('Metabolic Syndrome X') AND ('Exercise' OR 'Motor Activities'). A second literature search was performed in MEDLINE using the following title MeSH terms: 'Metabolic Syndrome' OR
'Syndrome X' AND 'Combined.' In addition, the reference lists from published (original and review) articles were searched manually to identify other potentially eligible studies.

Inclusion Criteria

Studies that met the following requirements were included in the systematic review: (i) randomised clinical trials or clinical trials that investigated the effect of exercise (dynamic endurance exercise, dynamic resistance exercise, or a combination); (ii) the duration of intervention was at least 4 weeks; (iii) the intervention was conducted in adults (>18 years) who had MetS (according to the National Cholesterol Education Program Adult Treatment Panel III of 2001 or International Diabetes Federation of 2005) but no other cardiovascular disease; (iv) the study was published in a peer-reviewed journal in or before November 2021.
For inclusion in the study, each study had to have a control group; studies with specific groups of participants, such as pregnant women and children, those comparing training at different physical exercise intensities (high-intensity training and moderate-intensity training), and those that did not include individuals with MetS were excluded from the review. Articles that were duplicated in the databases used in this study were excluded. Following the examination, seven publications were considered suitable for inclusion in this study. Figure 1 depicts the PRISMA diagram used for the study and selection of journal articles.

Measured Outcomes

The primary outcomes were changes in cardiovascular risk factors associated with MetS, including waist circumference, fasting plasma glucose, systolic and diastolic blood pressure, HDL cholesterol, and triglycerides. The secondary outcomes included peak oxygen uptake (VO_{2peak}), body weight, body mass index (BMI), fat mass, total cholesterol, low-density lipoprotein cholesterol, and plasma insulin.

Data Extraction
Data extraction was conducted independently by two unblinded reviewers (N.P. and S.R.T.E.). A data extraction sheet designed for this study was used to collect information on the study source, study design, participant characteristics, exercise characteristics, and outcomes observed in each study. Disagreements were resolved either by consensus or by the involvement of a third reviewer (A.S.M. Jr.).

Study Quality
We evaluated the quality of the study by administering an 11-item questionnaire that included questions about the eligibility criteria, randomisation, concealed allocation, similarity of baseline values, blinding of therapists and/or assessors, key outcomes, intent-to-treat analysis, between-group differences, and point and variability

measures. The PEDro scale was used to assess the quality of the study (1). The validity and reliability of the PEDro-scale have been confirmed in multiple studies (6, 7). For exercise intervention studies, the quality criteria 'blinding of participants' and 'blinding of therapists' were considered non-relevant; hence, we did not include either criterion. The questions were binary in nature (yes [1] or no [0]). The lowest possible score was 0, and the highest possible score was 9, with a higher number indicating better research quality.

RESULTS
Study Characteristics:

Amanat et al. (8) conducted a study on 57 middle-aged women with MetS who were overweight. The participants were divided into three exercise groups (control, aerobic exercise, and resistance exercise) and one control group. After 12 weeks of training, an increase was observed in the levels of irisin-1 (in the aerobic and resistance exercise groups) and nesfatin-1 (in all groups) in the participants. In addition, compared with participants in the control group, participants in the three exercise groups showed positive changes in anthropometric indices, lipid profile, and insulin resistance (Table 1).

Table 1. Key results from studies

Bateman et al. (9) conducted a cohort study with 86 individuals (age: 18 to 70 years) with MetS and a sedentary lifestyle, randomised into three exercise groups (RT, AT, and combined training (AT/RT)). The diastolic and mean arterial blood pressure of the participants decreased with AT/RT, and the body mass and triglyceride levels of the participants decreased with both AT/TR and AT. RT was found to be superior to AT in improving muscle strength and lean body mass. In addition, RT improved the glucose tolerance and insulin sensitivity of insulin-resistant individuals.

De Oliveira et al. (10) showed that exercise affects insulin resistance and beta-cell activity in individuals with systemic autoimmune myopathies (SAMs). This prospective study was conducted with nine patients with SAMs (six with dermatomyositis, two with antisynthetase syndrome, and one with polymyositis). Patients were instructed to performed aerobic and resistance exercises twice weekly for 12 weeks. Anaemia, insulin resistance, and T-cell function were assessed at baseline and post-intervention. The patients with stable illness had an average age of 46.7 years. The intervention did not affect the clinical or analytical parameters. After 12 weeks, the aerobic capacity, muscular strength, and function of the patients improved ($P < 0.05$), but their body compositions were unaltered. The results of the oral glucose tolerance test indicated that exercise did not affect the area under the curve (AUC) of glucose but lowered the insulin and C-peptide AUCs ($P < 0.05$). The Matsuda index and homeostasis model assessment (HOMA)2%, both of which are indices for insulin resistance, also improved significantly ($P < 0.05$). Exercise increased the aerobic capacity, strength, and function, reduced insulin resistance, and improved the cell function metrics of the patients. These

findings suggest that fitness training may help patients with SAM with metabolic issues.

Dutheil et al. (7) conducted a cohort study with 78 participants (age: 50 to 70 years) with MetS and a sedentary lifestyle. The participants were randomised into three training groups: High- moderate aerobic resistance (Re); Moderate resistance (30%) - high aerobic (70%) (rE) and Moderate resistance (30%) - moderate aerobic (30%) (re). A reduction in fat mass was primarily observed in Re and rE participants. The lean mass and body weight of participants in the training groups were reduced. Re participants showed a greater decrease in body weight and BMI than re participants, and both Re and rE participants showed greater visceral fat loss than re participants. In addition, Re participants showed a greater increase in strength than re participants. The carotid intima-media thickness, blood glucose level, HbA1c, triglyceride level, and high-sensitivity polymerase chain reaction results improved in participants from all training groups, and the HDL level also increased. The cardiovascular risk and MetS parameters improved in patients from all training groups.

Gallo–Villegas et al. (11) compared the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on insulin resistance, muscle mass, muscle activation, and serum musclin levels in healthy adults with MetS. Fasting glycaemia, insulinemia, and glycated haemoglobin of participants were measured before and after a treadmill workout. One-minute high-intensity phases at 90% VO_{2peak} were included in the HIIT regime (n = 29). In a 30-minute session, the MICT (n = 31) group trained at 60% VO_2. The average age of the participants was 50.8 ± 6.0 years, their BMI was 30.4%, and the VO_{2peak} was 29.0%. No change was observed in the HOMA-IR, carnosine levels, or musclin levels between the HIIT and MICT participants. HIIT increased the carnosine levels of participants by 0.66 mmol/kg (95% confidence interval: 0.08-1.24). A low insulin resistance and a greater lean mass/height^2 and VO_{2peak} were observed with both therapies. Both therapies caused a non-significant decrease in the musclin levels of participants.

Moreno-Cabañas et al. (2) conducted a cohort study with 87 middle-aged adults with MetS randomised in a HIIT + RT group (n = 33), a HIIT + HIIT group (n = 33), and a control group (n = 21) for 16 weeks. Participants in both training groups showed improvements in cardiorespiratory fitness, as indicated by the maximum oxygen consumption, and MetS components. HIIT + RT reduced the body weight, BMI, waist circumference, and fasting glycaemia and improved the strength and power of the legs of the participants. Meanwhile, HIIT + HIIT improved the triglyceride levels and mean blood pressure of the participants.

Stensvold et al. (12) conducted a clinical trial with 31 participants with MetS, randomised into the following three groups: aerobic interval training group (AIT; n = 11), ST (n = 10), and control group (n = 10). The serum levels of IL-18, TNF-α, IL-6, high sensitivity C-reactive protein, and insulin changed in participants from all three groups. The eric IL-18 levels of participants reduced by 43% after AIT. With ST, the serum TNF-α level of participants increased by 10% from the pre- to post-workout phase. Although the TNF-α level did not change significantly from baseline in response to AIT, it was lower than those in the ST and control groups. Both AIT and ST reduced the total body fat, fat mass, and waist circumference of participants and improved their endothelial function. AIT increased the VO_{2max} of the participants by 11%, and ST increased their maximum leg strength by 45%.

DISCUSSION

The findings of this comprehensive review indicate that physical activity exerts a beneficial effect on MetS parameters (9).

Initially, findings from studies that investigated the effects of physical exercise via AT, RT, and combination training (CT) demonstrated that physical activity improves systemic blood pressure. CT was shown to lower the systolic blood pressure (SBP) and mean arterial pressure (MAP) of participants in a study conducted by Bateman et al. Tibana et al. showed that both RT and CT caused hypotension (by reducing the SBP of women with MetS post exercise), but the change was more pronounced in women with MetS who underwent CT (9, 13). De Souza et al. confirmed that CT helps lower blood pressure (4). Another study that explored the relationship between physical activity and changes in eating habits reported an association between physical exercise and improvements in the patterns of MAP and SBP (1).

Furthermore, Bateman et al. showed that CT reduced the body mass of participants. RT was found to be superior to aerobic exercise for increasing muscular strength and lean body mass in patients with terMetS. In a cohort study by Stensvold et al., which included 43 participants diagnosed with MetS, participants from all training groups, including CT, AT, and RT, showed a decrease in waist circumference, fat, and body mass, with no statistically significant differences between the groups. However, no notable differences in HDL levels were observed between the intervention and control groups. Another encouraging finding was the improvement in the endothelial function of participants after AT, RT, and CT therapies (9; 14).

Stensvold et al. reported the reduction of waist circumference, fat, and body mass in participants who underwent AT and RT therapies (12). CT was shown to cause a 6 cm reduction in waist circumference in a clinical experiment on 16 university students with obesity conducted by Ha et al. (15). Similarly, a clinical trial with 24 middle-aged, inactive women with obesity revealed the effectiveness of AT and RT in reducing the weight, body fat, waist circumference, and BMI of the participants (16). In another study on 87 middle-aged individuals with MetS, participants from the CT group exhibited statistically significant changes in terMetS

with respect to weight reduction, BMI, and waist circumference. With combined AT (HIIT + HIIT), the triglyceride levels of participants improved significantly (2).

Amanat et al. showed that participants from all groups engaged in physical activities showed improvements in anthropometric indices and lipid profiles and substantial reductions in body weight and BMI (8). In another study, in which both food adjustments and exercise were incorporated, participants had a smaller waist circumference and a lower proportion of body fat. Additionally, the AT group participants showed a decrease in body mass, whereas the RT group participants showed a decrease in HDL levels and an increase in fat-free mass (1). De Souza et al. conducted a clinical study in which 42 middle-aged men with irregular activity or a sedentary lifestyle were randomly assigned to undergo CT or AT and showed that both CT and AT lowered the waist circumference of the participants (4). In a clinical experiment on people with type 2 diabetes, AT group participants showed greater weight loss and BMI reduction, whereas CT group participants showed a greater reduction in waist circumference (6).

With respect to changes in the glycaemic pattern, Bateman et al. showed that among patients with insulin resistance, RT participants exhibited greater glucose tolerance and insulin sensitivity than AT and control participants. (9). In contrast, Moreno Cabanas et al. showed that participants who underwent CT showed statistically significant improvements in fasting blood glucose patterns (2). Other studies have also demonstrated a statistically significant reduction in insulin resistance in all intervention groups with physical exercises, and the statistically significant reduction in formamidopyrimidine DNA glycosylase expression, fasting insulin, and HOMA-IR in all interventions was noteworthy. Furthermore, the reduction in the parameters in the CT group participants were more substantial (8). In another study, the combination of physical activity with a healthy diet led to a reduction in fasting insulin levels (1).

Moreover, the outcome of a clinical experiment involving 251 persons with type 2 diabetes, revealed a significant shift in the HbA1c value, which was significantly higher in the AT group. Furthermore, a significant increase was observed in the HbA1c value in the RT group compared to that in the control group (6). In contrast, Stensvold et al. reported no differences in fasting glycaemia between the intervention and control groups in their study (14).

The VO_{2peak} in the AT and CT groups was shown to increase compared with that in the other groups (14). In a study of 87 middle-aged individuals with MetS, physical exercise increased the cardiorespiratory fitness of the participants, as measured using the maximal oxygen consumption, regardless of the group (2).

Notably, in a cohort study with 78 individuals with MetS (age: 50 to 70 years), all CT participants showed a reduction in the MetS parameters, with the most substantial reduction observed in participants who underwent strong RT with moderate-intensity aerobic exercise (7). Therefore, CT is useful for the treatment of MetS and improvement of its parameters; similar findings were reported by Said et al. (17).

An additional finding was the decrease in the expression of several pro-inflammatory cytokines in individuals with MetS after they performed resistance exercise. This observation was in addition to the reduction in metabolic indices.

According to Nikseresht et al., the IL-18 levels of participants increased after the cessation of resistance workouts. Stensvold et al. also reported variations in serum IL-18 levels in their study, with the greatest decline occurring after HIIT (2, 18).

Similarly, Amanat et al. showed an increase in the nefastin-1 levels of participants after the conclusion of exercise interventions in all groups. The authors reported a positive relation between irisin-1 levels and body weight, BMI, body fat percentage, fasting insulin, and HOMA-IR in their study. Previous studies have shown that nefastin-1 operates in the central nervous system as well as the digestive system and regulates hunger, caloric expenditure, and glucose concentration, among other functions (8).

Amanat et al. showed that the irisin-1 levels increased in both AT and CT group participants. Previous research has shown that an increase in irisin-1 levels is associated with increased physical activity, and this increase is associated with improvements in body composition. These findings lead us to the conclusion that in patients with MetS, physical activities help attenuate pro-inflammatory processes. (8, 18).

De Oliveira et al. showed that physical training affects insulin resistance and beta-cell activity in patients with SAMs. After 12 weeks of training, involving both aerobic and resistance exercises, the aerobic capacity, muscle strength, and function of participants showed improvement ($P < 0.05$), whereas their body composition did not change. Findings from oral glucose tolerance tests indicated that exercise did not affect the glucose AUC but decreased the insulin and C-peptide AUCs. The Matsuda index and HOMA2% (both insulin resistance indicators) also improved. Patients diagnosed with SAMs showed improvements in their aerobic capacity, strength, and function after they participated in exercise programs. Insulin resistance decreased and cellular function measures improved after exercise training (10). Gallo-Villegas et al. compared HIIT and MICT and found that both interventions decreased insulin resistance. The benefits of physical exercise in reducing insulin resistance in patients with MetS have been reported in a review (11, 19).

CONCLUSION

The findings from the reviewed articles indicate the superiority of combined training compared to the other forms of physical activity that were studied, with respect to the effectiveness in improving MetS parameters. This modality can be widely applied to the population, both to prevent MetS and improve MetS parameters in affected individuals. Further investigations are needed to better understand the impact of different types of training on diverse populations (different age groups, races, comorbidities, and medium and long-term effects).

Conflict of Interest

The authors declare that they do not have any information to disclose regarding conflicts of interest with respect to this manuscript.
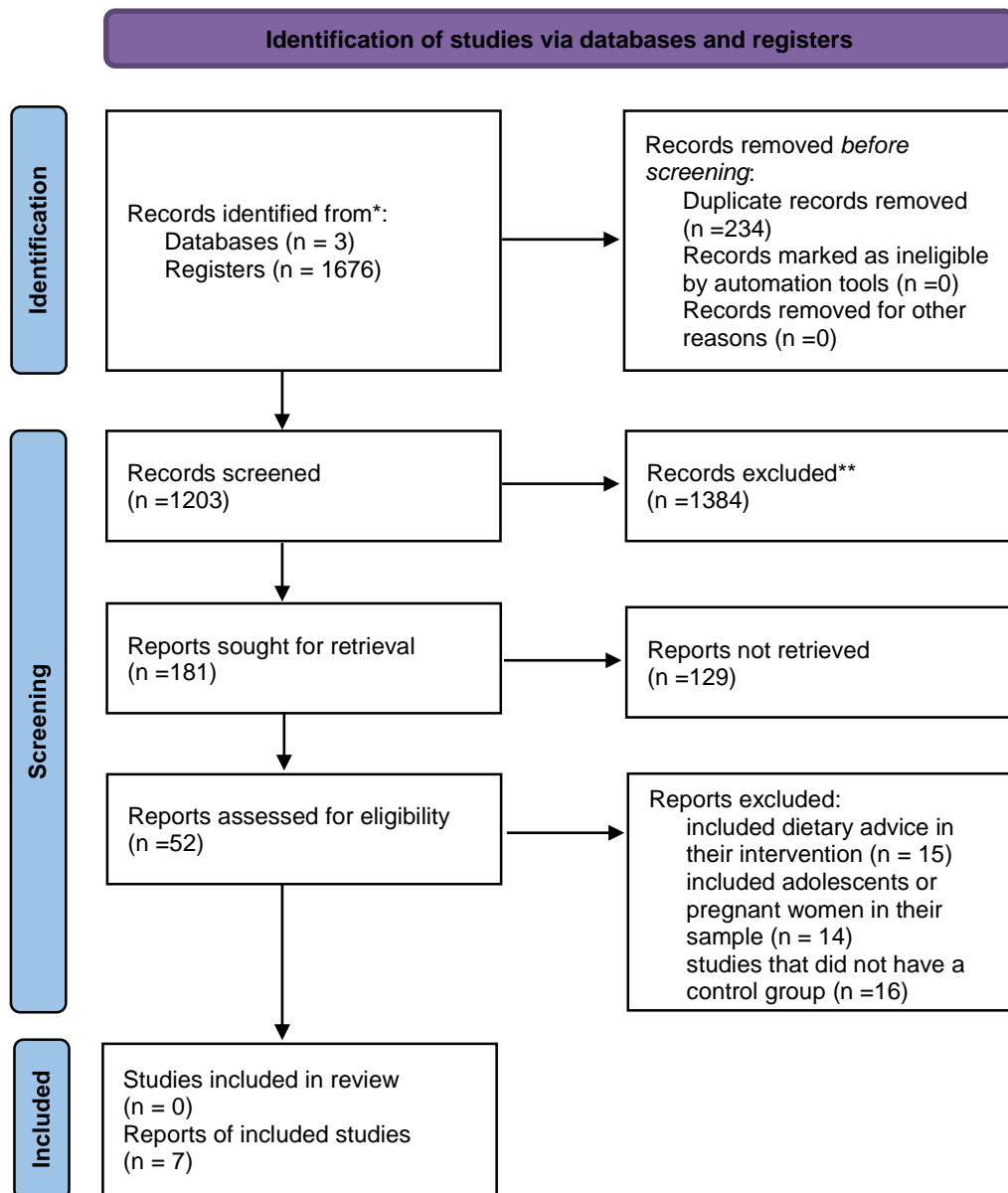
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FIGURE 1- PRISMA 2022 flow diagram for new systematic reviews which included researcher for databases, registers and sources.

Identification of studies via databases and registers

Identification

Records identified from*:
Databases (n = 3)
Registers (n = 1676)

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Records removed *before screening*:
Duplicate records removed (n =234)
Records marked as ineligible by automation tools (n =0)
Records removed for other reasons (n =0)

Screening

Records screened
(n =1203)

→

Records excluded**
(n =1384)

Reports sought for retrieval
(n =181)

→

Reports not retrieved
(n =129)

Reports assessed for eligibility
(n =52)

→

Reports excluded:
included dietary advice in their intervention (n = 15)
included adolescents or pregnant women in their sample (n = 14)
studies that did not have a control group (n =16)

Included

Studies included in review
(n = 0)
Reports of included studies
(n = 7)

*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Table 1. Key results from studies   Click here to access/download;Figure;Tabela 1. Main Results of Studies.docx

Article Name	Authors	Year of Publication	Journal Name	Methodology	Objectives	Results
A Randomized Controlled Trial on the Effects of 12 Weeks of Aerobic, Resistance, and Combined Exercises Training on the Serum Levels of Nesfatin-1, Irisin-1 and HOMA-IR	Amanat S; Koroni R; Bahramian M; Vaismoradi M; Fararouei M; Dianatinasab A.	2020	Frontiers in Physiology	Cohort study with 57 overweight middle-aged women with metabolic syndrome (MetS). Participants were randomised into three exercise groups (aerobic, resistance, and combined training) and one control group.	Analysing the changes in the levels of nesfatin-1 and irisin-1 and the metabolic and anthropometric indices after intervention with aerobic, resistance, or combined training for 12 weeks.	In all exercise groups, the levels of nefastin-1 and irisin-1 increased. In all intervention groups, the body weight and body mass index (BMI) of the participants reduced, and the anthropometric parameters improved. The irisin-1 levels were positively correlated with the body weight, BMI, body fat, fasting insulin, and HOMA-IR of participants. The nesfatin-1 levels were negatively correlated with the body fat and low-density lipoprotein cholesterol levels of participants. Insulin resistance decreased in the intervention groups, as did the FPG and fasting insulin levels and the HOMA-IR. The combined training group showed a greater reduction in the parameters.
Comparison of aerobic versus resistance exercise training effects on metabolic syndrome (from the Studies of a Targeted Risk	Bateman LA; Slentz CA; Willis LH; Shields AT; Piner LW; Bales CW; Houmard JA; Kraus WE.	2011	American Journal of Cardiology	Cohort study with 86 participants, aged between 18 and 70 years, with MetS and a sedentary lifestyle. The participants were randomised into three exercise groups: resistance training (RT),	Comparing the effects of TA on MetS and its risk factors with those of RT performed alone or in combination with TA.	TA/RT lowered the diastolic and arterial BP. TA/RT and TA reduced the body mass, triglyceride levels, SM z-score, and waist circumference of the participants. The peak VO$_2$ decreased with TA. RT improved the muscular strength and lean body mass of participants more effectively than TA. RT improved insulin resistance and glucose tolerance. TA/RT decreased the ATP III score, whereas RT increased it.

Reduction Intervention Through Defined Exercise - STRRIDE-AT/RT)				aerobic training (TA), and combined TA and RT (TA/RT).		
Different modalities of exercise to reduce visceral fat mass and cardiovascular risk in metabolic syndrome: the RESOLVE randomized trial	Dutheil F; Lac G; Lesourd B; Chapier R; Walther G; Vinet A; Sapin V; Verney J; Ouchchane L; Duclos M; Obert P; Courteix D.	2013	International Journal of Cardiology	Cohort study with 78 participants, aged between 50 to 70 years, with a sedentary lifestyle and with MetS. The participants were randomised into three training groups: 1) high-intensity resistance and moderate-intensity aerobic exercise (Ra); 2) moderate-intensity resistance (30%) and high-intensity aerobic exercise (70%) (rA); 3) moderate-intensity	Analysing the impact of physical activities of various intensities on visceral fat and cardiovascular risk (CVR) in individuals with MetS.	Participants in the Ra and rA groups lost weight. The training group participants lost lean mass and weight. Ra participants showed greater body weight and BMI reduction than ra participants. Ra and rA participants lost more visceral fat than ra. Ra participants gained greater strength than ra participants. Participants from all groups showed improvements in carotid intima-media thickness, blood glucose level, HbA1c, lipid level, and high-sensitivity C-reactive protein (high-sensitivity CRP) level, alongside improvements in CVR, MetS markers, and fitness.

				resistance and moderate-intensity aerobic exercise (ra).		
Effect of exercise training on inflammation status among people with metabolic syndrome	Stensvold D; Slørdahl SA; Wisløff U.	2012	Metabolic Syndrome and Related Disorders	Clinical trial with 31 participants with MetS. The participants were randomised into three groups, as follows: high-intensity interval group (AIT; n=11), strength training (ST; n=10), and control group (n=10).	Examining the effect of aerobic training versus strength training on the levels of circulating IL-18 and other pro-inflammatory markers in individuals with MetS.	The serum levels of IL-18, TNF-α, IL-6, high-sensitivity CRP, and insulin were altered. TIA decreased the serum IL-18 level by 43%. The serum TNF-α levels increased by 10% (P = 0.014) from pre- to post-ST. The TNF-α levels were lower after TIA than after ST (14%; P = 0.032) and control treatment (12%; P = 0.039).

Efficacy of high-intensity interval- or continuous aerobic-training on insulin resistance and muscle function in adults with metabolic syndrome: a clinical trial.	Gallo-Villegas J; Castro-Valencia L. A; Pérez L; Restrepo D; Guerrero O; Cardona S; Sánchez YL; Yepes-Calderón, M; Valbuena LH; Peña M; Milán AF; Trillos-Almanza M. C; Granados S; Aristizabal JC; Estrada-Castrillón M; Narvaez-Sanchez R; Osorio J; Aguirre-Acevedo DC; Calderón	2022	European Journal Of Applied Physiology	Fasting glycaemia, insulinaemia, and glycated haemoglobin were assessed using conventional methods; insulin resistance was evaluated using Homeostatic Model Assessment (HOMA), lean mass using dual-energy X-ray absorptiometry, muscle activation using carnosine with proton magnetic resonance spectroscopy, and musclin detection using an enzyme-linked immunosorbent assay before and after a supervised, three-times/week, 12-week	Assessing the efficacies of high-intensity, low-volume interval training (HIIT) and MICT on insulin resistance, muscle mass, muscle activation, and serum musclin levels.	Both AIT and ST decreased the body fat, fat mass, and waist circumference of participants. The endothelial function of participants improved. AIT increased the VO_{2max} by 11%, and ST increased it by 45%. The mean age of the participants was 50.8 ± 6.0 years, BMI was $30.6\ 4.0$ kg/m^2, and VO_{2peak} was 29.0 ± 6.3 mL.kg^{-1}.min^{-1}. HIIT did not yield better results than MICT in the reduction of Ln HOMA-IR (0.083 [95% CI 0.092 to 0.257]), carnosine and musclin levels or the thigh lean mass. After HIIT, the carnosine level of participants increased to 0.66 mmol/kg w.w. (CI 0.08– 1.24) Both therapies decreased insulin resistance, body fat, lean mass/height^2, and the VO_{2peak} of the participants. Both therapies exerted a marginal, non-significant effect on the musclin levels.

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Substitution of parts of aerobic training by resistance training lowers fasting hyperglycemia in individuals with metabolic syndrome	Moreno-Cabanas A; Ortega JF; Morales-Palomo F; Ramirez-Jimenez M; Alvarez-Jimenez L; Mora-Rodriguez R.	020	Applied physiology, nutrition, and metabolism	Cohort study with 87 middle-aged adults with MetS. The participants were randomised into a HIIT + resistance training (RT) group (n=33), a HIIT + HIIT group (n=33), and a control group (n=21) and evaluated for 16 weeks.	Measuring the evolution of MetS components, cardiorespiratory fitness, leg strength and power, fasting glucose levels, fasting insulin levels, and insulin resistance.	Participants from the training groups showed an increase in cardiorespiratory fitness, as measured using the maximum oxygen consumption (170 310- and 190 210-mL O 2 min -1; P 0.001) and the MetS z score (-0.12 0.29 and -0.12 0.31 for HIIT + RT and HIIT + HIIT, respectively; P 0.02). HIIT + RT decreased the body weight (-1.04, P = 0.038), BMI (-0.36, P = 0.047), waist circumference (-2.82, P < 0.001), and fasting blood glucose levels (-0.35, P = 0.005) of the participants. The participants from this group also showed an increase in leg strength and power determined using countermovement leaping

						(P = 0.002) and leg press 1 repetition max (21 % vs %; P 0.001). HIIT + HIIT reduced the triglyceride levels (-0.26, P = 0.002) and blood pressure (-3.72, P = 0.001) of the participants.
Exercise training attenuates insulin resistance and improves β-cell function in patients with systemic autoimmune myopathies: a pilot study.	de Oliveira DS; Borges I; de Souza JM; Gualano B; Pereira R; Shinjo SK.	2019	Clinical Rheumatology	This quasi-experimental, prospective study included nine patients with systemic autoimmune myopathies- (SAMs) (six patients with dermatomyositis, two patients with antisynthetase syndrome, and one patient with polymyositis). Patients underwent a 12-week, twice-a-week exercise training program comprising aerobic and resistance	Assessing the effects of exercise training on insulin resistance and β-cell function in patients with SAMs.	The patients were healthy and had an average age of 46.7 years. Clinical and analytical markers of the patients were unaffected by the therapy. After 12 weeks, the aerobic capacity, muscular strength, and function of the patients increased (P < 0.05). Exercise exerted limited effect on the glucose area under the curve (AUC); however, it decreased the insulin and C-peptide AUCs (P < 0.05). The Matsuda index and HOMA2% of the patients improved (P < 0.05). Exercise increased cell function and lowered insulin resistance in the patients. Thus, the data indicate that fitness training may improve metabolic SAMs.

				exercises. The disease status, aerobic capacity, muscle strength, body composition, insulin resistance, and β-cell function parameters were tested at baseline and after the intervention,		