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Exercise Training Modalities and Their Effects on Body Composition and Lipid Profiles in Men with Metabolic Syndrome: A Comparative Study

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Abstract

Background: Metabolic syndrome, a cluster of metabolic disorders including abdominal obesity, insulin resistance, dyslipidemia, and hypertension, is a major global health concern affecting 20-25% of adults worldwide and up to 35% in Iran. Physical activity has been identified as a non-pharmacological intervention to manage this condition by improving insulin sensitivity, lipid profiles, blood pressure, and body composition. This study assessed how aerobic, resistance, and combined training influence physiological parameters and body composition in men with metabolic syndrome to improve workplace productivity and employee health.

Methods: Conducted in 2023 on 110 men aged 20-50 years from Isfahan, participants were randomly assigned to four groups: aerobic (n=27), resistance (n=27), combined (n=28), and control (n=28). Over 12 weeks, the exercise groups followed structured training protocols while body composition and metabolic parameters were assessed pre- and post-intervention.

Results: This study highlights the effectiveness of combined exercise on various health parameters. Combined exercise resulted in the greatest reductions in weight (-5.3%), WHR (-7.1%), Percent Body Fat (-19.9%), body fat mass (-19.6%), TG (-42.6%), LDL-C (-43%), TC (-22.9%), and also led to significant increases in Fat Free Mass (+7%), Skeletal Muscle Mass (+11.5%), and HDL-C (+12.1%). Resistance training ranked second in effectiveness, followed by aerobic training. However, no significant differences were observed among the exercise types for percentage body fat and HDL-C improvements.

Conclusion: The combined training offers superior benefits for managing body composition and metabolic parameters in men with metabolic syndrome. These findings provide evidence for optimizing exercise interventions to improve health outcomes in this population.

Keywords: Exercise, Body Composition, Lipid Profiles, Metabolic Syndrome

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Introduction

Metabolic syndrome is defined as a set of metabolic disorders that include abdominal obesity, insulin resistance, dysregulation of blood sugar and lipids, and hypertension (1, 2). This syndrome is closely related to cardiovascular disease, hypertension, type 2 diabetes, and obesity (3, 4). According to the World Health Organization, approximately 20 to 25 percent of the world's adult population has metabolic syndrome (5, 6). A high prevalence of metabolic syndrome has been reported in Iran. Based on studies in Iran, the prevalence of metabolic syndrome in the adult population is estimated to be about 30 to 35% (7, 8).

Physical activity can be effective in the treatment of metabolic syndrome by improving, increasing HDL-C, lowering Triglycerides (TG), and blood pressure. In this regard, exercise activities have been considered as an effective non-pharmacological therapeutic intervention. Resistance, aerobic and combined training are each effective in improving the components of metabolic syndrome such as blood lipids, blood sugar control, blood pressure, and body composition. Aerobic training is one of the effective methods in controlling and managing metabolic syndrome. Among the positive effects of aerobic training in people with metabolic weight loss syndrome are blood sugar control: through improving insulin sensitivity and reducing the risk of type 2 diabetes, lowering blood pressure, improving blood lipid profile, lowering LDL-C (Low Density Lipoprotein), TG levels and increasing good cholesterol (High Density lipoprotein) (HDL-C), increasing tolerance to conditions Stress can be effective in the management of metabolic syndrome (7, 8). Strength training is also very effective for the management and control of metabolic syndrome by increasing blood flow and improving cardiac function, increasing muscle volume and metabolism, improving, strengthening muscle endurance, and increasing strength. Concurrent training has a greater effect on fat metabolism than aerobic and strength training (8, 9). However, there is limited evidence to compare the effectiveness of these three training methods on physiological parameters and body composition in patients with metabolic syndrome. The aim of this study was to compare the effect of aerobic, resistance, and combination training on physiological parameters and body composition in men with metabolic syndrome. This research was conducted with the objective of improving employees' health and enhancing workplace productivity through effective exercise interventions. This study aims to reduce the research gap in this field and provide more evidence about the best type of exercise for men with metabolic syndrome, and the results of this research can help provide the best exercise approach to manage and improve the condition of people with metabolic syndrome.

Previous studies have shown that combined training can be the most effective way to improve metabolic syndrome metrics and cardiovascular risk factors.

Material and method

This study was applied and quasi-experimental in terms of controlling the research variables, which was conducted in 2023 on 110 men with metabolic syndrome, living in the city of Isfahan. The selection of this sample was intentional, as the company's management places a strong emphasis on maintaining the physical health and overall well-being of its employees. The statistical population of this study consisted of men with metabolic syndrome from a home appliance manufacturing company in Isfahan province with a population of 18,000 people. Based on the results of health assessment and monitoring in 2023, 110 subjects based on the inclusion criteria of the study They were purposefully selected and randomly divided into four groups: aerobic training (27 subjects), resistance training (27 subjects), combined training (28 subjects), and control (28 subjects) groups. Informed consent was obtained from the participants and the necessary permissions were obtained with the IR Code of Ethics. IAU. NAJAFABAD. REC.2023.213 was obtained from the Ministry of Health.

Inclusion criteria included age range of 20 to 50 years, no medication, no specific underlying disease, no smoking, no chronic cardiovascular, kidney and thyroid disorders, no participation in the exercise program during the previous two months, lack of regular physical activity in the past year, and general physical and mental health. Participants should also have at least three of the five criteria of metabolic syndrome, including waist circumference to waist ratio. Upper pelvis (>0.9), HDL-C less than 50 mg/dl, TG greater than or equal to 150 mg/dl, fasting blood glucose >100 mg/dl, and blood pressure >130.85 mmHg/dHg were included. Exclusion criteria included bodily injury, withdrawal of the subject, non-observance of training principles, and absence of more than three sessions, based on which 8 Finally, 110 subjects (27 in the aerobic group, 27 in the resistance group, 28 in the combined training, and 28 in the control groups) completed the training programs for 12 weeks.

Blood samples were collected in two stages, 48 hours before the start of training (step 1) and 72 hours after the last training session (step 2). Blood samples were taken between 7 and 9 am at work by laboratory specialists and from the right arm vein of each subject in a sitting and resting position. Body composition was also measured using an InBody 270 device.

Workout Plan

The protocol of training was performed for 12 weeks and three sessions per week. Each session commenced with a 10-minute general warm-up, and concluded with a 20-40 main training, and 10-minute cool-down.

Aerobic Training

The aerobic training program involved participants walking and running on a treadmill at an intensity of 60 to 70% of their heart rate reserve (HRR). Throughout the 12-week program, both the duration and intensity of the training gradually increased, starting with 20-25 minutes at 60% HRR and progressing to 40 minutes at 70% HRR.

Resistance Training

In the first four weeks of resistance training, participants engaged in exercises such as leg presses, front and back leg extensions, chest presses, bent-over rows, lateral raises, triceps extensions, biceps curls, and two core exercises. Each exercise comprised three sets with a maximum of 10 repetitions, allowing for a 60-second rest between sets at 75% of their one-repetition maximum. In the subsequent four weeks, the training continued in a similar format but was adjusted to a maximum of 8 repetitions, with a 90-second rest between sets at 80% of their one-repetition maximum.

Combined Training

The participants in the combined training group followed the same schedule as those in the resistance and aerobic training groups. This schedule consisted of alternating sessions: one session dedicated to aerobic training followed by a session focused on resistance training. The intensity and duration of the training program for the combined group were consistent with those of both the aerobic and resistance groups.

Statistical analysis

To assess the normality of the data, the Shapiro-Wilk test was conducted ($p > 0.05$). To compare post-test means among three groups while accounting for pre-test covariates, ANCOVA was utilized ($p < 0.05$). For post-hoc analysis, the Bonferroni test was applied ($p < 0.05$). In cases where variables did not follow a normal distribution, the Kruskal-Wallis test was employed for group comparisons ($p < 0.05$), and pairwise comparisons were also conducted using the Kruskal-Wallis test ($p < 0.05$).

Results

The results of this study provide a comprehensive comparison of the effects of aerobic, resistance, and combined training on body composition and metabolic parameters in men with metabolic syndrome. Statistical analyses were conducted to evaluate changes in key variables, including weight, body fat percentage, skeletal muscle mass (SSM), lipid profiles, and blood glucose levels, across the four groups: aerobic training, resistance training, combined training, and control. Significant findings are summarized below. The mean and std of pre-test and post-test of body composition and metabolic parameter variables in the aerobic, resistance, combined, and control groups are presented in Table 1. Based on the Shapiro-Wilk test for normality ($p > 0.05$), variables weight, fat-free mass (FFM), LDL-C, and total cholesterol (TC) exhibited a normal distribution. Therefore, a Univariate Analysis of Covariance (ANCOVA) was employed to compare these variables across the four groups (aerobic, resistance, combined, and control) ($p< 0.05$) (Table 3), with Bonferroni post-hoc tests used for pairwise comparisons ($p< 0.05$) (Table 3). For variables not normally distributed, including BMI, body fat mass (BFM), waist-to-hip ratio (WHR), percentage body fat (PBF), skeletal muscle mass (SSM), HDL-C, and TG, the Kruskal-Wallis test was employed to assess differences among the groups, followed by Mann-Whitney U tests for pairwise comparisons where appropriate, providing a comprehensive analysis of the impact of different exercise modalities on both body composition and metabolic parameters ($p< 0.05$) (Table 5). The Kruskal-Wallis test revealed no statistically significant differences in BMI, and body fat mass (BFM) among the four groups ($p < 0.05$), indicating that the exercise interventions did not have a significant impact on these variables compared to the control group. However, a statistically significant difference in waist-to-hip ratio (WHR) was observed across the groups ($p < 0.05$). Mann-Whitney U tests revealed significant differences in WHR between the aerobic and combined groups (Mean Rank = 37.85 vs. 17.50, respectively) and between the resistance and combined groups (Mean Rank = 36.09 vs. 20.20, respectively). Combined group showed a greater decrease in WHR. There was no significant difference in WHR between the aerobic and resistance groups. There was significant difference in PBF between the four groups ($p < 0.05$), but no statistically significant difference was observed in PBF between aerobic, resistance, and combined groups ($p < 0.05$). However, there was a statistically significant difference in skeletal muscle mass (SSM) across the four groups ($p < 0.05$). Mann-Whitney U tests showed a significant difference between the aerobic and combined groups (Mean Rank = 22.72 vs. 33.09, respectively), with the combined group showing a greater increase in SSM. No significant differences in SSM were observed between the aerobic and resistance groups, or between the resistance and combined groups. The Kruskal-Wallis test showed statistically significant difference in TG levels across the groups ($p < 0.05$). Mann-Whitney U tests revealed significant differences between the aerobic and resistance groups (Mean Rank = 17.78 vs. 36.22, respectively), the aerobic and combined groups (Mean Rank = 36.76 vs. 19.55, respectively), and the resistance and combined groups (Mean Rank = 41.37 vs. 15.11, respectively). The Kruskal-Wallis test showed statistically significant difference in HDL-C levels across the groups ($p > 0.05$), but no statistically significant difference was observed in PBF between aerobic, resistance, and combined groups ($p < 0.05$).

Table 1. The Pre-Test and Post-Test of Aerobic, Resistance, Combined, and Control Groups on Body Composition and Metabolic Parameters

Group	Aerobic (n=27)		Resistance (n=27)		Combine (n=28)		Control (n=28)	
	Mean ± Std. Deviation		**Mean ± Std. Deviation**		**Mean ± Std. Deviation**		**Mean ± Std. Deviation**	
Variables	**Pre-test**	**Post-Test**	**Pre-test**	**Post-Test**	**Pre-test**	**Post-Test**	**Pre-test**	**Post-Test**
Height (Cm)	176.88 ± 6.57		178.11 ± 6.00		177.66 ±5.31		177.58 ± 6.20	
Weight (Kg)	87.95 ± 12.50	84.25 ± 12.50	85.66 ± 10.74	81.56 ± 10.74	88.82 ± 12.57	84.12 ± 12.57	87.64 ± 13.45	87.73 ± 13.31
BMI	28.08 ± 3.65	26.89 ± 3.65	27.04 ± 3.38	25.74 ± 3.35	28.16 ± 4.04	26.67 ± 4.01	27.76 ± 3.81	27.78 ± 3.82
WHR	0.96 ± 0.05	0.92 ± 0.03	0.95 ± 0.04	0.91 ± 0.03	0.94 ± 0.06	0.87 ± 0.03	0.97 ± 0.10	0.97 ± 0.10
BFM (Kg)	24.52 ± 8.66	21.82 ± 8.66	23.41 ± 5.63	19.11 ± 5.63	24.23 ± 9.17	19.53 ± 9.17	23.84 ± 8.30	23.92 ± 8.29
FFM (Kg)	63.43 ± 8.35	64.73 ± 8.35	62.25 ± 7.74	65.35 ± 7.74	64.59 ± 6.91	69.09 ± 6.91	63.80 ±8.77	63.72 ± 8.80
PBF (%)	27.48 ± 6.67	24.58 ± 6.67	27.18 ± 4.40	23.08 ± 4.40	26.67 ± 7.02	21.37 ± 7.02	26.79 ± 6.47	26.81 ± 6.48
SSM (Kg)	36.04 ± 5.05	37.29 ± 5.05	35.30 ± 4.71	38.85 ± 4.71	36.74 ± 4.15	40.89 ± 4.15	36.23 ± 5.32	36.13 ± 5.32
TG (mg.dl^{-1})	210.89 ±78.51	152.96±27.13	236.44±103.00	203.00 ±56.60	199.17±105.22	114.39 ±28.23	114.39 ±28.37	218.39±129.89
HDL-C (mg.dl^{-1})	41.59 ± 6.40	43.93 ± 5.71	38.56 ± 8.50	40.26 ± 8.29	39.82 ± 7.62	44.64 ± 7.12	38.11 ± 7.485	38.11 ± 7.485
LDL-C (mg.dl^{-1})	128.59 ±31.51	77.59 ± 13.12	121.44 ± 26.43	78.52 ± 12.37	123.93 ± 44.04	70.61 ± 11.99	114.93 ±35.03	114.61 ± 34.86
TC (mg.dl^{-1})	212.15 ±31.15	172.22 ±32.62	211.37 ± 29.63	165.59 ±28.12	200.71 ± 50.35	154.79 ±26.86	193.14 ±37.38	192.89 ± 39.25

Table 2. Shapiro-Wilk Test for Normality of Pre-Test Data

		Weight	BMI	WHR	BFM	FFM	PBF	SSM	TG	HDL-C	LDL-C	TC
Shapiro-Wilk	**Statistic**	0.98	0.95	0.09	0.18	0.98	0.97	0.98	0.17	0.97	0.98	0.98
	Df	110	110	110	110	110	110	110	110	110	110	110
	Sig.	0.12	0.01	0.01	0.00	0.35	0.02	0.35	0.15	0.02	0.29	0.32

P> 0.05.

Table 3. The Univariate Analysis of Covariance (ANCOVA) results for body composition and metabolic parameters between groups

Variables	Mean Square	F	Sig.	Eta partial Square	Observed Power
Weight (Kg)	131.26	2101.35	0.00*	0.98	1.00
FFM (Kg)	112.06	19250.39	0.00*	0.99	1.00
LDL-C (mg.dl^{-1})	12221.44	35.27	0.00*	0.50	1.00
TC (mg.dl^{-1})	8702.99	10.05	0.00*	0.22	0.99

p> 0.05.

Table 4. Pairwise Comparisons Using Bonferroni Adjustment for Body Composition and Metabolic Parameters between Groups

Variable	Groups	Mean Difference ± Std. Deviation	Sig.
Weight (Kg)	Aerobic vs. Resistance	0.40 ± 0.68	0.00*
	Aerobic vs. Combine	0.99 ± 0.67	0.00*
	Aerobic vs. Control	-3.79 ± 0.67	0.00*
	Resistance vs. Combine	.58 ± 0.68	0.00*
	Resistance vs. Control	-4.19± 0.68	0.00*
	Combine vs. Control	-4.78 ± 0.67	0.00*
FFM (Kg)	Aerobic vs. Resistance	-1.80 ± 0.02	0.00*
	Aerobic vs. Combine	-3.19 ± 0.02	0.00*
	Aerobic vs. Control	1.37 ± 0.02	0.00*
	Resistance vs. Combine	-1.39± 0.02	0.00*
	Resistance vs. Control	3.17 ± 0.02	0.00*
	Aerobic vs. Control	4.57± 0.02	0.00*
LDL-C (mg.dl^{-1})	Aerobic vs. Resistance	-2.78 ± 5.07	1.00
	Aerobic vs. Combine	5.77 ± 5.02	1.00
	Aerobic vs. Control	-40.57 ± 5.070*	0.00*
	Resistance vs. Combine	8.55 ± 5.02	0.54
	Resistance vs. Control	-37.78 ± 5.03	0.00*
	Combine vs. Control	-46.34 ± 4.99	0.00*

TC ($mg.dl^{-1}$)	Aerobic vs. Resistance	6.36 ± 8.00	0.42
	Aerobic vs. Combine	13.48 ± 7.98	0.09
	Aerobic vs. Control	-27.23 ± 8.06	0.01*
	Resistance vs. Combine	7.12 ± 7.97	0.37
	Resistance vs. Control	-33.59 ± 8.05	0.00*
	Combine vs. Control	-40.72 ± 7.88	0.00*

Table 5. Kruskal-Wallis and Mann-Whitney U Tests Statistics for Body Composition and Metabolic Parameters between Groups

Variables	Kruskal-Wallis Test				Mann-Whitney U Test					
	Four groups (Aerobic, Resistance, Combined, and Control)		Three groups (Aerobic, Resistance, and Combined)		Two groups (Aerobic, Resistance)		Two groups (Aerobic, Combined)		Two groups (Resistance, Combined)	
	df= 3		df= 2		df= 1		df= 1		df= 1	
	Kruskal-Wallis H	Asymp. Sig.	Kruskal-Wallis H	Asymp. Sig.	Z	Asymp. Sig.	Z	Asymp. Sig.	Z	Asymp. Sig.
Mean Rank BMI	3.79	0.28	-	-	-	-	-	-	-	-
Mean Rank WHR	24.89	0.00*	23.75	0.00*	-1.19	0.23	-4.49	0.00*	-3.69	0.00*
Mean Rank BFM	6.57	0.08	-	-	-	-	-	-	-	-
Mean Rank PBF	10.98	0.01*	3.76	0.15	-056	0.57	-1.81	0.07	-1.41	-1.62
Mean Rank SSM	11.40	0.01*	6.269	0.04*	-0.96	0.33	-2.40	0.01*	0.15	0.10
Mean Rank TG	47.33	0.00*	45.72	0.00*	-4.07	0.00*	-3.98	0.00*	-6.07	0.00*
Mean Rank HDL-C	11.41	0.01*	2.63	0.26	-1.34	0.17	-0.37	0.71	-1.42	0.15

Degree of Freedom: df; p< 0.05. - **Degrees of Freedom (df)**: Indicates the number of independent values that can vary in the analysis.

- **Kruskal-Wallis H**: The test statistic for the Kruskal-Wallis test.

- **Asymp. Sig.**: The p-value indicating statistical significance.

Discussion

This study aimed to evaluate the impact of aerobic, resistance, and combined exercise interventions on body composition and metabolic parameters, in comparison to a control group. The findings reveal differential effects across these exercise modalities.

Body composition changes

All training groups experienced significant weight loss, with the greatest reduction in combined training (5.3%), followed by resistance (4.8%) and aerobic training (4.2%), whereas the types of exercises had no significant effect on BMI compared to the control group. Liang et al.'s Study (2021) noted to no significant differences were observed between types of exercise (aerobic, resistance, and combined) in weight loss, although combined exercise provided the best results for improving other metabolic factors (8). Makiel et al.'s Study (2023) emphasized the reduction of body fat and increase in fat-free mass, but direct weight changes were not reported (10). Lima et al.'s research study reported 11 weeks with 16 participants, the study found a significant reduction in BMI across all training groups (11). Schmitt et al., while focusing on schizophrenia patients, highlighted the broader benefits of aerobic exercise in improving metabolic health and psychological symptoms. The positive impact of aerobic exercise on body weight, BMI (7). Pagan et al. reported improvements in BMI personalized training programs (12). Ramos-Campo et al.'s in review study (2021) reported Resistance circuit-based training resulted in reduced body fat and increased muscle mass, but overall weight changes were not mentioned (13). Lima et al. examined the effects of aerobic, resistance, and combined training on body composition in type 2 diabetes patients. The results showed a significant reduction in BMI across all training groups, indicating their effectiveness in reducing BMI(11). Zhou noted the groups with combined high resistance and low aerobic training (HRLAT) showed the largest improvements in BMI (9). In a meta-analysis, Liang et al. found that aerobic exercise was more effective than resistance training in improving BMI. However, no significant differences were observed among the exercise groups for weight(8).Most studies agree that combined (aerobic and resistance) training is the most effective method for improving body composition and reducing BMI. Some studies, such as Liang et al., found no significant differences among exercise types for weight loss (8), while others, like Zhou et al., showed greater effectiveness of combined training (9).

Combined exercise significantly lowered waist-to-hip ratio (WHR) compared to aerobic and resistance training alone, while no difference was found between the aerobic and resistance training groups. The waist-to-hip ratio (WHR), similar to waist circumference, serves as an indicator of abdominal adiposity and a potential risk factor for metabolic syndrome. Delgado-Floody et al. reported the resistance training+ high intensity interval training group showed significant reductions in waist circumference (WC) (14). Zhou et al. showed the improvements in WC in the high aerobic with low resistance training group (9). A combination of aerobic and resistance exercise is superior for reducing weight, waist circumference, and waist-to-hip ratio, which are crucial for improving metabolic syndrome markers, reducing visceral fat, and lowering the risk of metabolic syndrome (8).

While the exercise types did not significantly differentially impact body fat mass (BFM), all training groups significantly increased fat-free mass (FFM), especially with combined training (7%), and significantly reduced percent body fat (PBF) with comparable effectiveness across groups; combined training was also more effective than aerobic training for increasing skeletal muscle mass (SSM). This aligns with existing literature supporting the role of exercise in reducing overall adiposity. Pagan et al. reported improvements in lean mass, and fat percentage through personalized training programs (12). Makiel et al. demonstrated that combined training effectively increased fat-free mass, in men with metabolic Syndrome (10). Ramos-Campo et al. reported the resistance circuit-based training in comparing aerobic, resistance, and combined exercise effectively reduces total body fat and increases muscle mass in men with metabolic syndrome (13). The lack of significant differences in percentage body fat (PBF) between the exercise groups is also a point of concern, potentially indicating that the exercise interventions did not have a substantial impact on overall body fat percentage. This difference with other research might be attributed to the shared lifestyle factors among test subjects, such as prolonged work hours, and their geographic location.

While all exercise modalities led to notable weight loss compared to a sedentary control group, with combined training exhibiting the most pronounced effect, the underlying mechanisms likely involve a multifaceted interplay of hormonal and metabolic adaptations. Combined training may optimize these effects by concurrently increasing energy expenditure through aerobic components and stimulating muscle protein synthesis via resistance exercises, leading to increased lean mass and basal metabolic rate. Furthermore, the significant reduction in WHR with combined training, superior to both aerobic and resistance alone, suggests a targeted effect on abdominal adiposity, potentially driven by enhanced catecholamine-mediated lipolysis in visceral fat depots, which are particularly sensitive to exercise-induced sympathetic activation, thus contributing to improved metabolic profiles and reduced cardiovascular risk (8).

Metabolic Parameters Changes

The findings showed that all exercise groups experienced a significant decrease in LDL-C, with combined training leading to the highest improvement at 43%, followed by aerobic training at 39.7%, and resistance training at 35.3%. Although all exercise groups demonstrated significant reductions compared to the control group, there was no significant difference among the three exercise methods for lowering LDL-C. The results also indicated that the three types of exercise significantly increased HDL-C , with no significant differences observed among them, which is aligns with the meta-analysis by Liang et al. (2021), which also reported no significant differences among exercise groups for LDL-C and HDL-C (8).

Regarding TG levels, combined training was observed to be more effective than both aerobic and resistance training. While TC decreased across all exercise groups, with combined training exhibiting the largest reduction (22.9%), the differences among exercise types were not statistically significant. Zhou et al.'s study (2022) found that combined exercise prescriptions low resistance training (HALRT), high resistance with low aerobic training (HRLAT) were more effective than aerobic or resistance training alone in improving plasma lipid metabolism in elderly patients with metabolic syndrome, specifically showing significant improvements in LDL-C levels, TG, and TC. The HRLAT group showed greatest improvements in TC and LDL-C (9). Makiel et al. demonstrated that combined training effectively improved TG levels in men with metabolic syndrome (10). Liang et al. in meta-analysis evaluated the effectiveness of aerobic, resistance, and combined exercise on metabolic syndrome parameters across 15 randomized controlled trials involving 536 participants noted no significant differences were observed among the exercise groups for LDL-C, HDL-C, total cholesterol in MS (8).

The findings of this study highlight the differential impacts of aerobic, resistance, and combined training on body composition and lipid profiles in men with metabolic syndrome. Aerobic training significantly improved lipid metabolism by increasing HDL -C levels and reducing LDL-C and TG, aligning with its role in enhancing mitochondrial function and fat oxidation. Resistance training was particularly effective in improving insulin sensitivity and reducing TG, contributing to better lipid regulation. Combined training, however, demonstrated the most pronounced benefits, optimizing both lipid profiles and body composition by integrating the advantages of aerobic and resistance modalities. This approach not only reduced TG and LDL-C but also increased fat-free mass and skeletal muscle mass while decreasing abdominal adiposity, as evidenced by reductions in waist-to-hip ratio. Investigating the biological mechanisms underlying the effects of exercise on metabolic syndrome can provide valuable insights into the cellular and molecular pathways involved (15, 16). Studies have shown that aerobic and resistance training improve body composition and lipid profiles through regulation of metabolic hormones such as insulin (17), adiponectin (16), and leptin (17), increased expression of fat-metabolizing enzymes, and enhanced mitochondrial function (18). These results underscore the importance of tailored exercise interventions, with combined training emerging as the most effective strategy for addressing multiple metabolic pathways and improving health outcomes in individuals with metabolic syndrome. The optimal combination and intensity of aerobic and resistance exercise may vary depending on the individual's characteristics and health status, as highlighted by the differences in findings between studies focusing on specific populations (e.g., elderly individuals with metabolic syndrome). Further research is needed to optimize exercise prescriptions for different populations and to fully elucidate the underlying mechanisms responsible for the observed benefits. The limitations of some studies, particularly regarding methodological rigor, should be considered when interpreting the results. Future studies should focus on larger sample sizes, improved methodological quality, and longer follow-up periods to strengthen the evidence base. The observed discrepancies between our findings and those of other studies may be attributed to variations in study populations, intervention protocols, and methodological rigor. For example, Zhou et al. (2022) found that combined exercise prescriptions were more effective than aerobic or resistance training alone in improving plasma lipid metabolism in elderly patients with metabolic syndrome, which contrasts with the lack of statistically significant differences found in our study. These differing results underscore the importance of considering population-specific responses to exercise interventions.

Conclusion

This study was conducted to improve the health of male employees with metabolic syndrome, along with a sports approach to enhance work productivity, reduce healthcare expenses, and elevate overall quality of life within the company. Given that metabolic syndrome can lead to lower work efficiency and higher medical expenses, this research specifically focused on effective exercise interventions to address these issues.

Overall, the findings of this study support the notion that exercise, particularly combined aerobic and resistance training, is an effective strategy for improving metabolic health. This approach not only promotes fat loss but also helps in building and preserving muscle mass, leading to a healthier and more balanced body composition. These observations emphasize the need for further research to optimize exercise prescriptions for different populations and to fully elucidate the underlying mechanisms responsible for the observed benefits.

In a clinical context, the key point is that engaging in any form of exercise is significantly more beneficial than remaining inactive. While combined training may offer a marginal advantage, prioritizing an exercise regimen that is both sustainable and enjoyable is likely to yield better long-term adherence and health outcomes.

Considering the temporal, situational, and cultural contexts in which individuals work, employers in similar environments can leverage the results of this study to enhance employee productivity by promoting health initiatives. This approach can lead to better health outcomes for employees, ultimately benefiting organizational efficiency and reducing healthcare costs.

Limitations

There were several limitations should be considered when interpreting the results of this study. First, the study sample consisted of men with metabolic syndrome from a single company in Isfahan, which restricts the generalizability of the findings to other populations. Second, we lacked detailed control over the participants' dietary intake, introducing a potential confounding factor. Third, the follow-up period was relatively short, limiting our ability to determine the long-term effects of the exercise interventions. In addition, the study could not be blinded, which may have introduced bias due to participant or trainer expectations. The study lacked strict dietary control, which may have influenced metabolic parameters and body composition. Finally, although the participants were randomly assigned to groups, the purposeful method of initial selection could introduce a selection bias into this study.

Future Research

Future research should focus on several key areas to deepen understanding and enhance the reliability of findings. Increasing sample sizes is essential to improve statistical power and ensure that results are robust and generalizable across diverse populations. Additionally, incorporating individuals from various age groups and genders will allow for a broader understanding of exercise effects across diverse demographics. Conducting multi-center studies across different regions can further enhance the research by evaluating how cultural and geographical variations influence physiological responses, leading to more comprehensive and applicable findings. Extending study durations would allow researchers to evaluate long-term effects and the sustainability of interventions, providing a clearer picture of their efficacy over time. Future research should focus on tailoring exercise programs based on individual characteristics to optimize their impact on metabolic syndrome. Additionally, incorporating dietary assessments and standardized meal plans could help minimize confounding effects, ensuring more precise evaluation of exercise interventions. Investigating novel exercise combinations, including high-intensity interval training (HIIT) or advanced hybrid training models, may further enhance metabolic syndrome management. Additionally, investigating the underlying biological mechanisms driving observed changes is critical. This could include measuring hormones, inflammatory markers, and other physiological indicators to uncover pathways and processes that contribute to the outcomes. Such efforts would not only strengthen the scientific foundation of the research but also open avenues for targeted interventions and personalized approaches in the future.

Declarations

Not applicable

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Conflicts of interest

The author no conflict of interest in this study.

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