Aerobic Exercise Improves the Parameters of Metabolic Syndrome

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04/17/2020

Abstract

Metabolic Syndrome (MetS) is a complex condition with multiple metabolic imbalances. The key pathological feature of MetS is the accumulation of visceral fat (VF). The excessive deposits of the VF lead to systemic inflammation and cellular dysfunction in the muscle, liver, and other tissues. About one-third of the current U.S. population has MetS, and two-thirds have excessive body weight. The diagnostic criteria of MetS include enlarged waist circumference (WC), dyslipidemia, dysglycemia, and hypertension. MetS leads to increased morbidity and mortality, enormous healthcare expenditures, and increases the risk of development of cardiovascular disease (CVD), type two diabetes (T2D), insulin resistance (IR), non-alcoholic steatohepatitis (NASH), systemic inflammation, and different malignancies. Lifestyle modification is a crucial component of MetS treatment. Regular aerobic exercise (AE) can lead to the loss of the VF and significant improvements in other MetS parameters. The purpose of this study was to assess whether the AE improved the parameters of MetS. The presented ten clinical trials evaluated the effects of the different types and intensity of AE on the parameters of MetS in adults of different ages and cultures. The presented research concluded that AE significantly improved multiple MetS parameters, such as postprandial and fasting insulin and glucose, insulin sensitivity, IR, high-density (HDLc) and low-density lipoprotein cholesterol (LDLc), triglycerides (TGs), blood pressure (BP), glycosylated hemoglobin (HbA1c), WC, body mass index (BMI), and VF.

Keywords: aerobic exercise, insulin resistance, metabolic syndrome, visceral fat.

Introduction

MetS develops because of the disturbances in glucose, lipid, and amino acid metabolism; gradually, these imbalances lead to the accumulation of excessive abdominal and VF (Lee et al., 2018). The excessive deposits of the VF lead to systemic inflammation and cellular dysfunction in the muscle, liver, and other tissues. Currently, about one-third of the U.S. population has MetS, and two-thirds are overweight or obese (Copstead & Banasik, 2018). At least three features have to be present in MetS: increased WC 40 inches or more in men and 35 – in women, BP 130/80 mm Hg or higher, TGs 150 mg/dL or greater, blood glucose 100 mg/dL or higher, or HDLc less than 40 mg/dL in men or 50 – in women (Swarup & Zeltser, 2019). The healthcare costs of MetS-related medical issues are enormous. MetS increases the risk of developing CVD, IR, T2D, NASH, and various malignancies (Swarup & Zeltser, 2019).

A sedentary lifestyle is one of the risk factors for the development of MetS, associated morbidities, and diminished quality of life; physical inactivity leads to a higher prevalence of dyslipidemia, high BP, obesity, MetS, and T2D (Patel et al., 2017). In addition to total daily sitting time, the prolonged uninterrupted sitting behavior can worsen the MetS and CVD markers (De Jong et al., 2018). The lifestyle modifications that reduce body weight and VF deposits can significantly improve the risk of development and progression of MetS and its comorbidities (Swarup & Zeltser, 2019). Movement is one of the most influential health-supporting behavior; the recent meta-analysis found beneficial effects of AE (moderate and vigorous-intensity) on adiposity, BP, and fasting glucose (Biddle et al., 2019). Replacing the sedentary time with the increased AE duration and frequency is a practical approach for the reduction of risk of MetS and related pathologies. People who walk between 10,000 and 12,000 steps daily have lower BMI, VF, body fat percentage, WC, and waist-hip ratio (Chiang et al., 2019). Frequent interruptions of sitting time with walking breaks can increase energy expenditure, improve the postprandial glucose and insulin levels, and positively impact metabolic health in overweight adults (De Jong et al., 2018).

An AE is any activity that uses large muscle groups and relies on ATP energy produced by aerobic metabolism; it includes walking, jogging, running, swimming, cycling, dancing, and hiking. In the AE, the cardiorespiratory system supplies oxygen for the utilization by the skeletal muscles. The measurement criterion for the AE is the peak oxygen consumption (Patel et al., 2017). To improve the body composition, body weight, and metabolic health, the adults can engage in moderate-intensity aerobic exercise (MIAE) for a minimum of 150 minutes, vigorous-intensity - for 75 minutes every week, or in an equivalent mix of activities. Increasing the weekly MIAE to or beyond 300 minutes or vigorous - 150 minutes can provide additional health benefits (Williams, Rawson, & Branch, 2019). The fat-burning effect of the AE begins at the 40-50% of maximal heart rate (HR); the more vigorous intensity of AE results in a higher caloric loss (Williams et al., 2019). Regular AE can preserve pancreatic function and carbohydrate metabolism and reverse the pathology of MetS (Malin et al., 2018). This paper aims to investigate whether AE improves the parameters of MetS in adults.

Methods

The initial search for the scholarly articles performed on LIRN, ProQuest, Google Scholar, and PubMed revealed 320 studies. The search keywords included “MetS and aerobic exercise,” “exercise and weight loss,” “MetS and exercise,” “exercise and insulin resistance,” “exercise and visceral fat.” Applying the filters (adult human subjects, free full text, and clinical trials done within the last five years) reduced the results to 78 studies.

Results

Biddle et al. (2018) examined the effect of physical activity on metabolic markers in 435 overweight adults at risk for the T2D during a 36-month follow-up. The participants tracked their activity levels with an accelerometer for seven days, 24 hours a day. The researchers measured the BMI, serum glucose, and insulin (fasting and two-hour postprandial) and calculated the insulin sensitivity indexes (HOMA-IS and Matsuda-ISI). The stepping behavior resulted in the improvements in postprandial insulin and glucose and Matsuda-ISI. The stepping (walking) activity and the maintenance of the daily active time benefited metabolic health in the at-risk populations (Biddle et al., 2018).

In an eight-week randomized controlled trial (RCT), Chiang, Chen, Hsu, Lin, and Wu (2019) evaluated the effect of AE on MetS markers in 32 obese, 18-24-year-old adults. Two intervention groups, a walking group (WG) and walking and exercise group (WEG) maintained a daily average of 12,000 steps. The WEG group engaged in MIAE three times a week and tracked their daily activities with a smartwatch. The authors measured body composition and MetS parameters. The WG showed improvement in HDLc, while the body composition remained unchanged. The WEG significantly improved hip circumference, VF, HDLc, fasting glucose, TGs, BP, and HR. Achieving the daily step goal of 12,000 was only partially efficacious; the combination of daily 12,000 steps with MIAE allowed to make significant improvements in MetS markers (Chiang et al., 2019).

In a cross-over RCT, De Jong et al. (2018) compared the effects of the micro-bouts of activity (MA) and continuous activity (CA) on the MetS markers in 22 sedentary obese adults, both at the workplace and outside of work setting. The MA group interrupted the sedentary work every hour with five-minute MIAE, and the CA group had one daily 45-minute MIAE during a work break. The CA group increased the total daily steps and energy expenditure to a greater extent. Both groups significantly reduced the serum fasting insulin and improved insulin sensitivity and a self-perceived vigor (De Jong et al., 2018).

In an eight-week RCT, Jang, Paik, Ryu, Lee, and Kim (2019) compared the effects of AE versus resistance exercise on the MetS parameters in 24 obese women. The subjects participated in the MIAE four times a week, for 50 minutes, using treadmills or weight machines. Both groups significantly improved the body weight, BMI, WC, VF, and serum apelin-12 and lowered the risk for CVD (Jang et al., 2019).

In a 12-month intervention trial, König, Hörmann, Predel, and Berg (2018) investigated the effect of the dietary and exercise interventions on the metabolic health and body composition in 2,227 obese prediabetics. The intervention consisted of 41 physical activity sessions, 12 self-management classes, and eight nutrition lectures. At the end of the study, 839 subjects reversed prediabetes and normalized their serum HbA1c, and 766 - reversed the MetS. The participants significantly reduced body weight, WC, and BP and improved total cholesterol, TGs, and physical performance. This dietary and exercise program reduced the prevalence of MetS and the risk of development of T2D (König et al., 2018).

In a 12-week trial, Lee at al. (2018) evaluated the effect of the high-intensity 60-minute cycling and strength training on the insulin sensitivity and plasma sulfur-containing amino acids (SCAA) in 26 sedentary overweight adults. The authors monitored the metabolic parameters (BMI, MRI of muscles and fatty tissue, biopsy, and serum) and dietary intake. At the end of the study, the subjects significantly improved insulin sensitivity and serum SCAA, which associate with glucose metabolism. Both acute and long-term exercise improved the mitochondrial function in skeletal and adipose tissues and the sensitivity to oxidative stress (Lee et al., 2018).

In an eight-week RCT, Pourranjbar, Arabnejad, Naderipour, and Rafie (2018) examined the effects of the AE on IR and serum myonectin in 80 overweight and obese women. The AE group engaged in three weekly 45-minute running sessions at 50-70% maximal HR. The AE resulted in a significant decrease in IR and BMI and an increase in serum myonectin, which increased the uptake of the fatty acids. The AE reduced the risk of IR, T2D, and CVD in overweight adults (Pourranjbar et al., 2018).

In a three-month RCT, Russo et al. (2018) evaluated the effect of the AE on the expression of the inflammatory miRNAs and IL-8 in 68 obese adults. The AE group received 26 AE sessions lasting 90 minutes twice a week and nutrition consultations to reduce calorie intake. At the end of the study, the AE group significantly decreased their BMI, body weight, WC, IL-eight, total cholesterol, LDLc, Hb1c, and miRNA-146a-5p. The miRNA expression predicted a positive response to AE in obese adults (Russo et al., 2018).

In a randomized 13-day trial, Malin et al. (2018) compared the impacts of the high-intensity intermittent training (HIIT) and continuous exercise (CE) on the beta-cell function in seven obese adults with prediabetes. Both groups exercised for 60 minutes daily at the intensity of 70% maximal HR. The subjects had an *ad libitum* dietary intake reflected on the food logs. The authors monitored plasma glucose, insulin, C-peptide, body fat, muscle mass, VF, skeletal muscle insulin sensitivity, and hepatic and adipose IR. Both groups reduced body weight, serum glucose, and IR, as well as increased skeletal muscle insulin sensitivity, disposition index, and hepatic insulin extraction. The short-term exercise training increased beta-cell function in adults with prediabetes; it promoted a metabolic collaboration between muscle, gut, and pancreas to reduce ambient glucose levels (Malin et al., 2018).

Similarly, Cuddy, Ramos, and Dalleck (2019) aimed to examine the effect of the high-intensity interval training (HIIT) and MIAE on the cardiometabolic markers in 32 participants in the eight-week randomized trial. The HIIT group demonstrated more favorable improvements in cardiorespiratory fitness, BP, WC, and MetS severity; the HIIT elicited more potent and efficient improvements in MetS in comparison with MIAE (Cuddy et al., 2019).

Discussion

The purpose of this paper is to assess whether the AE improves the clinical parameters of MetS. The presented ten clinical trials enrolled the male and female subjects of different ages (18-75-years old) and cultures (Australia, Germany, Iran, Italy, Scandinavia, South Korea, U.K., and the U.S.A). All subjects were obese or overweight and had MetS. The researchers implemented different design and statistical analysis to evaluate the effects of such AE as walking, stepping, HIIT, and MIAE on Mets parameters. In some studies, the subjects participated in continuous AE while in others – in micro-bouts of AE. The trials varied in length, design, and the number of participants and utilized different tracking approaches – pedometers, smartwatches, self-reporting questionnaires, or professional supervision. Five studies had an RCT design. All trials reported the intervention-induced improvements in multiple MetS parameters (postprandial and fasting insulin and glucose, insulin sensitivity, IR, HDLc, LDLc, TGs, BP, HbA1c, WC, BMI, and VF).

Additionally, the researchers noticed improvements in physical performance, cardio-respiratory fitness, HR, self-perceived vigor, oxidative stress, cellular function (pancreatic beta-cells), mitochondrial function in muscle and adipose cells. Moreover, the subjects reduced the symptoms of prediabetes and T2D and reversed the parameters of MetS. The characteristic limitations of these studies include small sample size (22-2,227 subjects), short duration (three days - 36 months), possible errors (measurements, recall, or self-reporting data), generalizability, and confounding bias (unaccounted differences in lifestyle, medications, diet, nutrients, and other variables). While all of these trials measured the objective parameters of MetS, only one study also tracked the changes in the subjective parameters (self-perceived vigor and performance). Each study had additional unique strengths and limitations.

The trial by Biddle et al. (2018) included three levels of significance, the objective measurement of daily activities, the compositional data analysis of all daily behaviors (sitting, standing, sleeping, and stepping), and adjustments for multiple confounders. The generalizability (30-75-year-old U.K. adults at risk for T2D) and a cross-sectional design limited trial's validity and causality (Biddle et al., 2018). The strengths of the study by Chiang et al. (2019) include its design, and its limitations – generalizability (18-24-year-old obese Australian students) and dietary differences. De John et al. (2018) designed a robust trial; its limitations included generalizability (19-45-year-old obese, sedentary adults), and a lack of blinding. The study by Jang et al. (2019) had a robust design; the generalizability (50-61-year-old non-working, obese, menopausal, South Korean women), and a lack of regular exercise experience in the subjects limited the trial's validity. König et al. (2018) enrolled a large sample size; however, it lacked an RCT design and had limited generalizability (German subjects with prediabetes). Lee et al. (2018) implemented multiple measurements; a lack of randomization and generalizability (40-65-year-old Scandinavian men) limited the results. Pourranjbar et al. (2018) designed a robust trial; its generalizability (35-45-year-old Iranian women with abilities to run daily) limited the trial's validity. Russo et al. (2018) implemented a robust design; however, it had potential confounding bias (dietary modifications and caloric reduction) and limited generalizability (50-54-year-old Italian adults). Malin et al. (2018) provided multiple measurements; it lacked the control group and blinding and had limited generalizability (59-64-year-old subjects with prediabetes). The trial by Cuddy et al. (2019) had a robust design; its generalizability (high-risk sedentary faculty at a workplace setting) and a lack of control group limited the trial's validity.

The presented studies assessed the effect of AE on the parameters of MetS. In the majority of these studies, the researchers measured the objective data (intensity, duration, and frequency of AE, number of steps, anthropometrics, and blood tests). All these studies reported significant improvements in such MetS parameters as BMI, VF, lipidemia, glycemia, BP, WC, and IR in obese and overweight adults.

Conclusion

The presented studies support the thesis statement that the AE improves the clinical markers of the MetS in overweight and obese adults. The MetS is a complex metabolic condition that increases the risk of abdominal obesity, IR, T2D, CVD, liver steatosis, and various malignancies. Different types of AE that induced weight loss and reduction of VF significantly improved the clinical parameters and progression of MetS.

The future cohort and RCT studies can further assess the impact of different types of AE as well as their levels of intensity, duration, and frequency on the markers of MetS in the subjects of various ethnicities. Future studies can utilize larger sample sizes and longer follow-ups, include multiple objective and subjective parameters, estimate the dose-response effects, and investigate additional mechanisms of action of AE. Controlling the confounding factors (lifestyle, environment, diet, and macro- and micronutrient variations) can improve the validity of the outcomes.

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Appendix

A List of Abbreviations

AE	Aerobic exercise
BMI	Body-mass index
BP	Blood pressure
CVD	Cardiovascular disease
HbA1c	Hemoglobin H1c (glycosylated)
HDLc	High-density lipoprotein cholesterol
HIIT	High-intensity interval training
HR	Heart rate
IR	Insulin resistance
LDLc	Low-density lipoprotein cholesterol
MetS	Metabolic syndrome
MIAE	Moderate-intensity aerobic exercise
NASH	Non-alcoholic steatohepatitis (also known as fatty liver)
SCAA	Sulfur-containing amino acids
TGs	Triglycerides
T2D	Type two diabetes
VF	Visceral fat
WC	Waist circumference