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ZDRAVLJE SPORT REKREACIJA

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4TH INTERNATIONAL ONLINE CONFERENCE

HEALTH SPORT RECREATION

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BELGRADE, SERBIA / BEOGRAD, SRBIJA

MAY 14th, 2021 / 14. MAJ 2021.

Organiser of the Conference:
College of Sports and Health, Toše Jovanovića 11, Belgrade

Publisher:
College of Sports and Health, Toše Jovanovića 11, Belgrade

Editors:
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Graphic Design:
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ISBN: 978-86-83687-31-2

THE EFFECTS OF AEROBIC, RESISTANCE OR COMBINED TRAINING ON METABOLIC SYNDROME CLINICAL BIOMARKERS: A SHORT REVIEW

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Abstract: Metabolic Syndrome (MetS) is a common metabolic disorder characterized by a cluster of factors include dysglycaemia, elevated blood pressure, elevated triglyceride levels, low high-density lipoprotein cholesterol levels, and central obesity. Sedentary lifestyle and low physical activity levels increased the interrelated risk for cardiovascular diseases and metabolic disorders. The aim of this short review was to analyse the effects of aerobic, resistance and combined training on MetS clinical biomarkers. Following the Preferred Reporting Item for Systematic Reviews and Meta-analyses (PRISMA), a systematic search of relevant English-language articles was performed from earliest record to March 2020. The literature search was performed by seven online databases specifically Web of Science (WoS), PubMed and SCOPUS. The literature search returned 14,912 articles (WoS=2,359; PubMed=1,392 and SCOPUS=11,161); 21 full-text articles were reviewed after screening procedures. From the reviewed studies, aerobic exercise was reported in nine studies and the resistance exercise was reported in five studies. The combined training (or multicomponent exercise) was reported in seven studies. Overall exercise modes decreases the MetS clinical biomarkers, however, the aerobic training seemed to be the most efficient exercise mode. Moreover, the resistance exercise appears to have a positive effect on MetS prevention when associated with aerobic exercise. Aerobic and resistance exercises can contribute significantly to metabolic syndrome prevention and reduce the associated risk of cardiovascular disease and metabolic disorders. Combining exercise modes (i.e. combined or multi-component training) could be a valid strategy to control the metabolic syndrome clinical biomarkers.

Keywords: metabolic syndrome; cardiovascular disease; physical activity; exercise.

INTRODUCTION

Metabolic syndrome (MetS) is a common metabolic disorder characterized by a cluster of factors including dysglycemia, elevated systolic (SBP) or diastolic blood pressure (DBP), elevated triglyceride levels (TG), low high-density lipoprotein cholesterol (HDL-C) and increased waist circumference (WC) (Alberti et al., 2009; Raposo et al., 2017). The combination of these factors increase the risk of cardiovascular disease and metabolic disorders such as type 2 diabetes mellitus (T2DM) (Li et al., 2018; Shin et al., 2018).

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This article is a result of the project "GreenHealth - Digital strategies in biological assets to improve well-being and promote green health" (Norte-01-0145-FEDER-000042), supported by North Portugal Regional Operational Programme (NORTE 2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF)

Several MetS definitions and clinical guidelines have been developed for the respective diagnosis (Alberti et al., 2009; Huang, 2009). First, MetS definition was proposed in 1998 by the World Health Organization (WHO) with the insulin resistance as the major underlying risk factor as well as two additional risk factors, including microalbuminuria and reduced glucose tolerance (WHO, 1999). In 1999, the European Group for the Study of Insulin Resistance (EGIR) proposed an amendment for WHO's definition (Huang, 2009). In addition, in 2001, the guidelines from the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) required these major criteria, but not the insulin resistance per se (Grundy Scott M. et al., 2005).

The International Diabetes Federation (IDF) and the American Heart Association/National Heart, Lung and Blood Institute (AHA/NHLBI) presented different MetS criteria, regarding risk factors and cohort values (Zimmet et al., 2005). Presently, there are efforts to harmonize MetS criteria by framing the main differences between definitions: elevated WC (i.e. population- and country-specific delimitations), elevated TG (i.e., ≥150 mg/dL or 1.7 mmol/L), reduced HDL-C (i.e., <40 mg/dL or 1.0 mmol/L in males; <50 mg/dL or 1.3 mmol/L in females), elevated SBP (i.e., ≥130 mmHg), elevated DBP (i.e., ≥85 mmHg) and elevated fasting glucose (i.e., ≥100 mg/dL or 5.6 mmol/L) (Alberti et al., 2009).

The prevalence of MetS has been increasing in all age/ethnic populations (Li et al., 2018; Raposo et al., 2017), primarily due to modifiable factors, such as increased sedentary lifestyle, physical inactivity and hypercaloric diet (Myers et al., 2019; Pérez-Martínez et al., 2017). Effectively, exercise and physical activity are recommended to manage and prevent individual risk factors for MetS (Pérez-Martínez et al., 2017). Current researches reported that there is an inverse correlation between the increase of physical activity levels and cardiorespiratory fitness and MetS prevalence (Myers et al., 2019). In fact, previous meta-analyses have identified the benefits of aerobic exercise, combined exercise and resistance exercise in people diagnosed wtih MetS in order to reduce cardiovascular risk (Wewege et al., 2018), sarcopenic obesity (Dieli-Conwright et al., 2018) and anti-inflammatory process (Yousefabadi et al., 2021). However, these studies did not focused on the associations between exercise mode (i.e., aerobic, resistance and combined) and cardiovascular fitness, obesity and risk of MetS.

Therefore, the primary purpose of this short review was to analyse the current literature about the effects of aerobic, resistance or combined training on MetS clinical biomarkers. Additionally, we aimed to verify the associations between exercise and cardiorespiratory fitness, obesity and MetS.

METHODS

Literature Search Strategy

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines and the population-intervention-comparators-outcomes (PICOS) design were followed to conduct this short review (Moher et al., 2009). The literature search was based on five databases: PubMed/Medline, Web of Science (Core Collection: Citation Indexes) and SCOPUS/ScienceDirect. The eligibility criteria were assured by PICOS approach and the following search strategy was defined: (1) population: individuals with MetS; (2) intervention: current research about effects of exercise on individuals with MetS; (3) comparison: aerobic, resistance or combined training; (4) outcomes: MetS clinical biomarkers; and (5) study design: experimental/quasi-experimental cross-sectional and longitudinal trials (e.g., crossover, controlled trial and randomised controlled trial).

According to the search strategy, studies April 2000 to April 2020 were included for relevant publications using keywords with a Boolean phrase: (("Metabolic Syndrome") AND ("Physical Activity" OR Exercise OR Training)). Duplicated articles were identified and eliminated prior to application of the selection criteria (inclusion and exclusion). Titles and abstracts were initially selected and excluded according to selection criteria.

Selection Criteria

The included studies in the present review followed these inclusion criteria: (1) studies with screening procedures based on MetS clinical biomarkers; (2) studies that provide the exercise mode for the associations between combined cardiovascular fitness, obesity and the risk of MetS through clinical biomarkers; (3) cross-sectorial or longitudinal cohort, case-control, and/or randomized controlled trials; (4) studies in humans with Sport Science and as Scope; (5) original article published in a peer-review journal; (6) full text available in English; and (7) article reported data collection, study design, procedures, and outcomes. The exclusion criteria were articles with bad quality screening by Downs Black checklist; and reviews, abstract/papers conference, surveys, opinion pieces, commentaries, books, periodicals, editorials, case studies, non-peer-reviewed text, or master's/doctoral thesis.

Quality Assessment and data extraction

The methodological quality was assessed using Dows and Black checklist for assessing the methodological quality of randomized and nonrandomized healthcare interventions. This checklist was used in previous reviews due their accuracy in the cross-sectional and longitudinal studies (Fox et al., 2018). Each item is scored as "1" (yes) or 0" (no/unable to determine), and the scores for each item provide the total quality score. The selection of full texts was based on a selection to determine the selection criteria: inclusion or exclusion. Dataset from the reviewed articles were organized according to: reference (year), country, gender, sample (N), age, exercise intervention (duration, frequency and intensity), outcomes, MetS criteria and quality assessment (QS). Sample characterization was reported as mean ± standard deviation, CI, and effect size (ES) wherever possible.

Disagreements were resolved through discussion between two authors, or via a third researcher if required. Each author performed the classification independently with subsequent inter-observer reliability analysis: kappa index (0.93) and confidence interval (CI): 0.92–0.95). In the evaluation of methodological quality, the mean quality score was 90.14 (min: 0.65, max: 0.89).

RESULTS

The literature search returned 14,912 articles (WoS=2,359; PubMed=1,392 and SCOPUS=11,161); 21 full-text articles were reviewed after screening procedures. From the reviewed studies, aerobic exercise (AE) was reported in nine studies (*n* = 9), the resistance exercise was reported in five studies (*n* = 5) and the combined training (AE/RT) was reported in seven studies (*n* = 7).

The reviewed articles were published between 2007–2020. The present review analysed a total of 1893 participants (min: 16, max: 453). The population of reviewed samples were from Australia (*n* = 1), Brazil (*n* = 3), Finland (*n* = 3), Italy (*n* = 1), Korea (*n* = 2), Norway (*n* = 2), Portugal (*n* = 1), Spain (*n* = 2), Sweden (*n* = 1), Iran (*n* = 1), United State of America (*n* = 5). The mean and standard deviation for age was 58.11 ± 4.37 years; the exercise intervention ranged 8-52 weeks (duration) and 3-7 day per week (frequency). The training intensity was reported using maximum heart rate (HRmax); heart rate reserve (HRR); lactate threshold (LT); repetition maximum (RM), rate of perceived exertion (RPE); maximum oxygen uptake (VO_2max), and peak aerobic capacity (VO_2peak). The reviewed studies used different MetS criteria's following AHA/NHLBI (*n* = 1), NCEP-ATP III (*n* = 9), IDF (n = 2) and harmonizing MetS definition by Alberti et al. (2009) (*n* = 2). Seven studies did not specify MetS definition to define the clinical biomarkers. Table 1 showed the main findings by the studies included in this review.

Table 1- Summary sampling representativeness, methodological procedures, outcomes and quality assessment about reviwed articles.

Reference (year)	Country, Gender	Sample (N)	Age	Exercise intervention				Outcomes	MetS Criteria	QS
				Duration (Wks)	*Frequency (Days/Wk)*	*Intensity*	*Training mode*			
Alvarez et al. (2018)	Brazil, F	43	45.6 ± 11	16	3	8 to 14 bouts - 30 to 58s jogging or running at 90% HRreserve (96-120 s rest, 70% HRreserve)	Aerobic	AE (HIIT) improved BG, HDL-C, LDL-C, BMI and cardio-respiratory fitness	IDF	0.87
Anderssen et al. (2007)	Sweden, M/F	137	45.9 ± 2.5	52	3	60 to 80% HRmax for 40 min 5 times a week	Aerobic	Both exercise and dietaryintervention reduced metabolic syndrome prevalence.	NCEP-ATP III	0.87
Irving et al. (2008)	US, M/F	27	51 ± 9	16	5	3d/wk between LT and VO_2 peak (RPE 15-17); 2 days at or below LT (RPE 10-12).	Aerobic	Body composition changeds with AE (i.e. HIIT) that was more effective for reducing total and sub-cutaneous abdominal fat.	NCEP-ATP III	0.78
Kang et al. (2016)	Korea, F	23	49.85 ± 11.0	12	5	60 to 80% HRmax or 40 min 5 times a week.	Aerobic	AE had beneficial effects on the resting heart rate, physical fitness, and arterial stiffness.	IDF	0.74
Lima et al. (2012)	Brazil, F	44	47.4 ± 1.8	12	3	60 to 70% HRmax (RPE 11-14)	Aerobic	AE proved MS components, but did not alter resting blood pressure or the BP response.	ND	0.65
Mora-Rodriguez et al. (2017)	Spain, M	40	54 ± 9	24	3	4 bouts – 4 min, pedalling at 90% HRmax (3min rest, 70% HRreserve)	Aerobic	AE (HIIT) significant decreased the WC, DBP. No significant differences were found for BG, HDL-C and TG levels.	Alberti et al. (2009)	0.87
Morales-Palomo et al. (2017)	Spain, M/F	49	54 ± 8	16	3	4 bouts – 4 min, pedalling at 90% HRmax (3min rest, 70% HRreserve)	Aerobic	AE (HIIT) significant decresead BG, SBP, DBP, WC, BMI and body weight.	ND	0.83
Stensvold et al. (2010)	Norway, M/F	22	50.2 ± 9.5	12	5	4 min intervals – walking/running at 90% HRmax (3min rest, 70% HRreserve)	Aerobic	AE (HIIT) descresead SBP and DBP; no changes in body weight, fasting plasma glucose, or HDL levels.	NCEP-ATP III	0.78
Straznicky et al. (2010)	Australia, M/F	40	50.2 ± 9.5	12	20	60% Hrmax (125-145 bpm)	Aerobic	BD, baroreflex sensitivity, and metabolic parameters improved significantly.	NCEP-ATP III	0.78
Cardoso et al. (2016)	Brazil, F	43	48.28 ± 6	12	3-5	10 to 12 repetitions - 50 to 80% 10RM	Resistance	RT do not affect glycaemia, BMI or MetS markers and lipidic peroxidation; however, increasing reduction BP.	NCEP-ATP III	0.74
DeVallance et al. (2016)	US, M/F	57	46 ± 11	8	3	60% 1RM (wk 1-2); 70% 1RM (wk 3-4); 80% 1RM (wk 5-6); 85%1RM (wk 7-8)	Resistance	RT did not decrease the group mean values of arterial stiffness in individuals with MetS or healthy controls	NCEP-ATP III	0.83
Mager et al. (2008).	Finland, M/F	57	46 ± 11	8	3	1x16 60% 1RM (month 1); 1x12 70% 1RM (months 2-5); 2x10-12 70%1RM (months 6-8)	Resistance	Weight, BMI or waist circumference and acute insulin response were stronger predictors of the ghrelin concentration.	NCEP-ATP III	0.83
Dadrass et al. (2019)	Iran, M	48	53.9 ± 7.11	12	3	60% 1RM (wk 1-2); 70% 1RM (wk 3-4); 80% 1RM (wk 5-6); 85%1RM (wk 7-8)	Resistance	Vitamin D supplementation in addition to RT had positive effects on some inflammatory markers,	ND	0.87
Venojarvi 2013	Finland, M/F	313	40-65	12	3-5	55% to 75% of HRreserve (wk 1 – 4 at 55%, wk 5 – 8 at 65%, and wk 9 – 12 at 75%).	Resistance	Weight, BMI or waist circumference and acute insulin response were stronger predictors of the ghrelin concentration.	ND	0.83
Annibalini et al. (2017)	Finland, M/F	16	55-70	12	3	**AE:** intensity (40% to 65% HRreserve) and duration (30 to 60 minutes); **RT:** 12 to 20 repetitions - 40 to 60% 10RM.	Combined	AE/RT has the potential to reduce the deleterious health effects associed to diabetes-related inflammation.	ND	0.78
Balducci et al. (2010)	Italy, M/F	82	62.1 ± 4.3	52	2	**AE:** intensity (40% to 65% HRreserve) and duration (30 to 60 minutes); **RT:** 12 to 20 repetitions - 40 to 60% 10RM.	Combined	AE/RT significant reduce the sensitivity-C reactive protein (hs-CRP) and other inflammatory biomarker, as wel the insulin resistance (independent weight loss).	AHA/NHLBI	0.89
Potteiger et al. (2012)	US, M/F	82	27-48	13	4	**AE:** 65 to 80% of HRmax; **RT:** high intensity days: 5 to 7 repetitions with 100% 5–7 RM; moderate intensity days: 8 to 10 repetitions with 80% of their 8–10 RM.	Combined	Both RT and AE exercise, with equal training frequency, session duration and energy restriction, improve the MetSyn clinical biomarkers.	NCEP-ATP III	0.89
Bateman et al. (2011)	US, M/F	196	49.5 ± 3.3	17	≥2	**AE:** ~120 minutes/week at 75% VO_2max; **RT:** 3 days/week, 3 sets/day of 8 to 12 repetitions of 8 different exercises targeting all major muscle groups.	Combined	Combined AT and RT was similarly effective but not different from AT alone that was the most efficient exercise mode for improving cardiometabolic health.	NCEP-ATP III	0.87
Choi et al. (2013)	Korea, M/F	453	52.3 ± 14.3	12	5	**AE:** intensity of 60–75% of the age-predicted HRmax (300 kcal/session); **RT:** to 20 repetitions - 40 to 60% 10RM	Combined	Combined exercise program significantly decreased CTRP 3 levels and modestly increased CTRP-5 levels.	ND	0.78
Da Silva et al. (2020)	Portugal, M/F	39	67.0 ± 6.7	12	3	**AE:** between 60 and 70% of the Hrmax (RPE 2-5); **RT:** 8–15 repetitions, with a 1–2 min a rest interval.	Combined	Short-term exercise mode and intensity may differently impact the metabolic profile of individuals with MetS, particularly RT with HIIT.	Alberti et al. (2009)	0.82
Dieli-Conwright et al. (2014)	US, M/F	82	62.1 ± 4.3	16	3-4	**AE:** 30 minutes at 65-80% HR maximum; **RT**: 3 sets of 10 repetitions, 45 second rest between sets.	Combined	Metabolic-related effects for combined AE and RT reduces the metabolic syndrome and prevent cardiovascular disease and diabetes.	ND	0.78

AE –Aerobic exercise; AE/RT – Combined exercise; AHA/NHLBI – American Heart Association/National Heart, Lung, and Blood Institute; BG – Blood glucose; BMI – Body Mass Index; CTRP – C1q/tumor necrosis factor-related protein; DBP – diastolic blood pressure; F – Female; HDL-C - low high-density lipoprotein; *HIIT – High intensity; interval training;* HRmax – maximum Heart Rate; HRR – Heart Rate reserve; IDF – International Diabetes Federation; LDL-C – low-density lipoprotein; LT – lactate threshold; M - Male; MetS – Metabolic Syndrome; NCEP-ATP III – National Cholesterol Education Program Adult Treatment Panel III; ND – not described; RM – repetition maximum; RPE – rate of perceived exertion; RT – Resistance exercise; SBP – systolic blood pressure; TG – triglyceride; US – United State of America; VO_2max – maximum oxygen uptake; VO_2peak – peak aerobic capacity; WC – Waist Circumference; *Wk – Week (s)*

DISCUSSION

The present short review was focused on two purposes: (1) to analyse the current literature about the effects of aerobic, resistance or combined training on MetS clinical biomarkers; (2) to verify the associations between exercise and cardiorespiratory fitness, obesity and MetS. Results showed that the three exercise modes decrease MetS clinical biomarkers. Nevertheless, there were some differences among them.

Aerobic exercise displayed marked benefits concerning MetS prevalence. Particularly, high intensity interval training (HIIT) improved BG, HDL-C, LDL-C, body composition (i.e. body weight, total and sub-cutaneous abdominal fat). Additionally, a baroreflex sensitivity was also verified in aerobic exercise, with influence in MetS clinical biomarkers (Alvarez et al., 2018; Irving et al., 2008; Mora-Rodriguez et al., 2017; Morales-Palomo et al., 2017; Stensvold et al., 2010). However, the influence of HIIT remains controverse. Mora-Rodriguez et al. (2017) verified a significant decrease in WC and DBP but no significant differences in BG, HDL-C and TG levels. Moreover, Stensvold et al. (2010) found a decrease in SBP and DBP but no changes in body weight, fasting plasma glucose or HDL levels. Contrarily, Mora-Rodriguez et al. (2017) presented a significant decrease in BG, SBP, DBP and WC concerning body mass index (BMI) and body weight.

The influence of resistance training benefits in MetS prevention was not as robust as if there was an aerobic component. Effectively, two studies revealed no interaction effects between resistance exercise and glycemia, BMI, MetS markers and lipid peroxidation, with a small reduction in BP (Cardoso et al., 2016; DeVallance et al., 2016). In addition, BP values did not decrease significantly comparing individuals with MetS to healthy individuals (DeVallance et al., 2016). Indeed, the weight, BMI, WC and acute insulin responses were stronger predictors for MetS clinical biomarkers (Mager et al., 2008). Resistance exercise appears to have a positive effect on MetS prevention when associated with aerobic exercise. Both resistance and aerobic exercise, with equal training frequency, session duration and energy restriction, improve MetS clinical biomarkers (Da Silva et al., 2020; Dieli-Conwright et al., 2014; Potteiger et al., 2012). Nevertheless, combined exercise proved to be an effective strategy to reduce MetS clinical biomarkers but not significantly different than isolated aerobic training, which seemed to be the most efficient exercise mode to improve cardiometabolic health in different target populations (i.e. diabetics, menopausal women, patients with overweight/obesity and cancer) (Bateman et al., 2011).

There are some limitations that should be addressed in the practical application of this review. First, there were many different methodological approaches in the reviewed studies, particularly in exercise intervention. Exercise duration, frequency and intensity were different between follow-ups, as well as sampling representitiveness. Second, future investigations should consider a meta-analytic procedure to clarify the extent of the effects. Third, we have only considered full-text articles available in English, which constitutes a language limitation in the literature search strategy. More important, further investigation should be more focused on the target population (e.g diabetes, woman menopause, overweight/obesity and cancer).

CONCLUSION

Physical activity and exercise are positive cost-effective interventions to reduce MetS prevalence. Moreover, aerobic and resistance exercise can contribute significantly to MetS prevention and to reduce the associated risk of cardiovascular disease and metabolic disorders. This way, combining aerobic and resistance exercise with different intensities could be a valid strategy to control MetS clinical biomarkers.

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