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Original paper

Positive impact of a 4-week duration supervised aerobic training on anthropometric, metabolic, hemodynamic and arterial wall parameters in metabolic syndrome subjects

Ieva Slivovskaja [a,d], Jurgita Buzinskaitė [d], Ligita Ryliškytė [b,d], Jūratė Balsytė [b,c,d*], Rokas Navickas [b], Roma Puronaitė [b,c,d], Agnė Jucevičienė [b,c,d], Alvydas Juocevičius [d], Aleksandras Laucevičius [b,c,d]

[a] *Department of Rehabilitation, Physical and Sports Medicine of Institute of Health Sciences of the Faculty of Medicine, Vilnius University, Vilnius, Lithuania*

[b] *Clinic of Cardiac and Vascular Diseases, Institute of Clinical Medicine of the Faculty of Medicine, Vilnius University, Vilnius, Lithuania*

[c] *State Research Institute Centre for Innovative Medicine, Vilnius, Lithuania*

[d] *Vilnius University Hospital Santaros Klinikos, Vilnius, Lithuania*

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Summary

Objectives: Metabolic syndrome (MetS) is linked to the development of type 2 diabetes and increased risk of cardiovascular disease (CVD). Physical inactivity is one of the main pathophysiological factors of MetS subjects. The aim of this study was to evaluate if 4-week supervised aerobic training had any impact on anthropometric, metabolic, hemodynamic and arterial wall parameters in MetS subjects.

Design and methods: 57 MetS subjects were randomly selected from a Lithuanian High Cardiovascular Risk (LitHiR) national primary prevention programme. Hemodynamic, cardiometabolic risk and arterial wall parameters were evaluated after the 4-week supervised aerobic training.

Results: After 4 weeks of aerobic training there was statistically significant decrease in body mass index from 30.58 ± 3.7 to 30.3 ± 3.55 kg/m^2 ($p = 0.010$), waist circumference from 104.24 ± 9.46 to 102.9 ± 9.48 cm ($p = 0.003$), decrease of LDL cholesterol from 4.21 ± 1.15 to 3.78 ± 1 mmol/l ($p = 0.032$) and high sensitivity C-reactive protein from 2.01 ± 2.36 to 1.64 ± 1.92 mg/l ($p = 0.009$), decrease of diastolic blood pressure (BP) from 83.06 ± 10.18 to 80.38 ± 8.98 mmHg ($p = 0.015$), mean BP from 100.03 ± 10.70 to 97.31 ± 8.88 mmHg ($p = 0.027$) and aortic stiffness, assessed as carotid-femoral pulse wave velocity, from 8.34 ± 1.26 to 7.91 ± 1.15 m/s ($p = 0.034$).

Conclusions: In subjects with MetS even short-duration (4-week) supervised aerobic exercise training is associated with improvement of some anthropometric, metabolic and hemodynamic parameters as well as the decrease in aortic stiffness. This training modality could be recommended for initiation of physical training and could increase motivation for further physical activity.

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Keywords: metabolic syndrome, physical inactivity, supervised aerobic exercise training, aortic pulse wave velocity

Introduction

Metabolic syndrome (MetS) subjects have a 5-fold increased risk of diabetes [1,2] and 3-fold increase of cardiovascular disease (CVD) mortality compared to the individuals without MetS [2]. The role of physical inactivity and obesity is growing in the development of CVD and type 2 diabetes mellitus (T2DM) [3,4]. According to the results of Lithuanian High Cardiovascular Risk (LitHiR) primary prevention programme, the incidence of MetS in the middle-aged population in Lithuania is 28.7% [5]. Sedentary lifestyle was found in 49.9% (in 54.4% of women and in 43.1% of men) of these subjects [6].

* Corresponding address: Jūratė Balsytė, Vilnius University Hospital Santaros Klinikos, Santariškių str. 2, LT-08661 Vilnius, Lithuania. Tel.: +370 688 62514.
E-mail: jurate.balsyte@gmail.com (J. Balsytė).

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Although the positive effect of aerobic activity in improvement of cardiovascular health is well accepted, the European Society of Cardiology has concluded that it has not yet been established how much exercise is required in order to improve the lipid profile and reduce cardiovascular risk [7].

Pathological changes of arterial wall parameters – arterial stiffness and carotid intima-media thickness – have been demonstrated to be prognostic markers for future cardiovascular events [8]. Changes of anthropometric, metabolic and arterial wall parameters occurring after supervised aerobic physical training could contribute to dynamic assessment of cardiovascular risk in MetS subjects and significantly enhance the motivation of these subjects for physically active lifestyle and physical training. Most of the previously conducted physical training interventional studies in MetS patients lasted 8 weeks and more [9–11]. Furthermore, none of them have compared the effects that occur as early as after 4 weeks of the supervised aerobic exercise training.

Objectives

The main purpose of this study was to evaluate if short 4-week duration supervised aerobic exercise training has any influence on metabolic syndrome parameters (anthropometric, metabolic) and to analyse dynamics of arterial wall parameters after training in metabolic syndrome subjects without overt diabetes mellitus and cardiovascular disease.

Design and methods

Study population

Our study subjects were randomly recruited from the participants of LitHiR (Lithuanian High Cardiovascular Risk) national primary prevention programme [3,5] between 2009 and 2014. The study prospectively included 57 individuals with MetS diagnosed on the basis of updated NCEP ATP III criteria [12].

All participants were physically inactive – performing less than 150 min/week of the moderate intensity physical training. The mean age of the subjects in the study was 52.79 $\pm$ 6.65 years, among them were 31 (54.4%) females and 26 (45.6%) males. Arterial hypertension was present in 53 (93%) of subjects. Dyslipidaemia was present in 55 subjects (96.5%), among them elevated LDL cholesterol (LDL-Chol) was present in 50 subjects (91%), elevated triglycerides (TG) in 36 (65.5%), decreased HDL cholesterol (HDL-Chol) in 27 (49.1%) subjects. There were 50 (87.7%) patients with central obesity and 28 (49.1%) cases of fasting dysglycaemia.

The investigation conforms with the principles outlined in the Declaration of Helsinki and was approved by the local ethics committee. Informed consent was obtained from all subjects.

Clinical assessment

The evaluation of anthropometric parameters and metabolic profile included weight, body mass index (BMI), waist circumference, blood pressure, venous blood samples for blood lipid levels, fasting glucose, high sensitivity C-reactive protein (hsCRP) as well as the arterial wall parameters assessed prior to and after 4-week of supervised aerobic physical training. All laboratory tests and arterial wall parameters were obtained at rest in the morning after an overnight fast.

Supervised aerobic physical training protocol

The 4-week exercise training protocols were applied. Specifically, the training intervention consisted of a 4-week duration supervised aerobic training for 30–40 min/day, 5 days/week. Exercise intensity was gradually increased from 40% to 60% of heart rate reserve (HRR). HRR is the difference between maximum heart rate and resting heart rate. Heart rate reserve was used to calculate heart rate exercise zones by the Karvonen Formula [13,14]. The ERS-2 Ergoline bicycle system (Ergoline GmbH) allowing to control the exercise load was used for the titrated exercise training.

Arterial wall parameters

Noninvasive assessment of arterial wall parameters was carried out by measuring aortic and peripheral arterial stiffness, and the common carotid artery intima-media thickness prior to and after the 4-week exercise training. Aortic and arterial stiffnesses were assessed by an applanation tonometry system (SphygmoCor v.8.0; AtCor Medical) [15]. Measurements of carotid–femoral pulse wave velocity (cfPWV in m/s, so-called aortic stiffness), carotid-radial pulse wave velocity (crPWV in m/s, so-called peripheral artery stiffness) and aortic augmentation index (AIxHR@75, %) were performed before and after the supervised aerobic training.

Common carotid intima media thickness (cIMT, μm), carotid artery distensibility and nondimensional index Quality Carotid Stiffness (QCS) of common carotid artery (CCA) [16] were measured using a high-resolution echo-tracking system (Art. Lab, Esaote Europe B.V.).

Statistical methods

Statistical analysis was performed using STATISTICA 10. Data were checked for normality using Shapiro–Wilk test. Differences between baseline and follow-up measurements were tested with paired Student's t-test or Wilcoxon signed-rank test, as appropriate. All p values were two-tailed and the level of significance was set to 0.05.

Results

Training-induced changes of anthropometric parameters and metabolic profile

The 4-week duration supervised aerobic physical training was associated with a statistically significant ($p < 0.05$) decrease in weight, BMI, waist circumference, LDL-Chol and hsCRP (Table 1).

Training-induced changes of hemodynamic and arterial wall parameters

The 4-week duration supervised aerobic physical training was associated with a statistically significant ($p < 0.05$) decrease of diastolic and mean BP but not systolic pressure.

We analysed the dynamics of arterial wall parameters by comparing them before and after training – aortic stiffness (cfPWV, m/s), and peripheral artery stiffness (crPWV, m/s), augmentation index (AIxHR@75, %), carotid stiffness (QCC) and carotid intima-media thickness (cIMT, μm). Statistically significant decrease of aortic (cf-PWV) stiffness was found in the study group. Peripheral (crPWV) artery stiffness showed the tendency of diminishing but it did not reach the statistical significance. Changes in carotid stiffness (QCS) and carotid intima-media thickness (cIMT) was not observed in our cohort at all (Table 2).

Table 1.
Training-induced changes of anthropometric and biochemical parameters

Parameter	4-week training		
	Baseline	After training	*p*-value
Weight, kg	89.28 ± 14.04	88.52 ± 13.21	**0.008**
BMI, kg/m^2	30.58 ± 3.7	30.3 ± 3.55	**0.010**
Waist, cm	104.24 ± 9.46	102.9 ± 9.48	**0.003**
Total-Chol, mmol/L	6.42 ± 1.24	5.94 ± 1.63	0.063
LDL-Chol, mmol/L	4.21 ± 1.15	3.78 ± 1.26	**0.032**
HDL-Chol, mmol/L	1.12 ± 0.25	1.14 ± 0.27	0.928
TG, mmol/L	2.61 ± 2.72	2.26 ± 1.91	0.339
Fasting glucose, mmol/L	5.65 ± 0.46	5.65 ± 0.52	0.704
hsCRP, mg/L	2.01 ± 2.36	1.64 ± 1.92	**0.009**

BMI – body mass index, HDL-Chol – high density lipoprotein cholesterol, hsCRP – high sensitivity C-reactive protein, LDL-Chol – low density lipoprotein cholesterol, TG – triglycerides, Total-Chol – total cholesterol.

Table 2.
Hemodynamic and arterial parameters

Parameter	4-week training		
	Baseline	After training	*p*-value
Heart rate, b/min.	63.24 ± 8.02	61.96 ± 9.06	0.332
Systolic BP, mmHg	133.96 ± 14.01	131.19 ± 11.47	0.129
Diastolic BP, mmHg	83.06 ± 10.18	80.38 ± 8.98	**0.015**
Mean BP, mmHg	100.03 ± 10.70	97.31 ± 8.88	**0.027**
PWV radial, m/s	9.37 ± 1.49	8.94 ± 1.46	0.113
PWV femoral, m/s	8.34 ± 1.26	7.91 ± 1.15	**0.034**
AIxHR@75, %	22.17 ± 12.12	19.06 ± 3.72	0.080
IMT, μm	622.03 ± 82.62	639.17 ± 75.86	0.066
Carotid stiffness	4.04 ± 1.53	4.07 ± 1.26	0.495

AIxHR@75 – aortic augmentation index, BP – blood pressure, IMT – intima-media thickness, PWV – pulse wave velocity.

Discussion

The growing prevalence of obesity and increased incidence of MetS, that are considered to be precursors of T2DM and CVD, become a problem in the world [17,18]. Sedentary lifestyle is the predominant risk factor in subjects with MetS [19–22]. One of the most effective tools to prevent the manifestation and development of MetSis improving the adherence to physical activity. The lack of motivation for starting the measures that improve physical fitness and continuing physical activity for a long time is the major problem in MetS subjects. Furthermore, the optimal modality and duration of physical training needed to improve the metabolic profile and reduce cardiovascular risk is not yet established [7]. Various modalities of physical training – aerobic, aerobic interval, strength – are used in MetS subjects [10,23,24]. Since previous studies usually implemented 8 or more week duration training programmes in these subjects [9–11,25], we assessed if short 4-week duration supervised aerobic physical training could have some initial impact on anthropometric, metabolic, hemodynamic and arterial wall parameters in MetS subjects. We have demonstrated that short-duration supervised aerobic physical training improves anthropometric parameters, metabolic profile, and arterial wall parameters, and could serve as the initial step for continuous improvement of physical activity. Training-induced reversal of arterial wall stiffness would result in a decrease of cardiovascular risk in these subjects and additionally motivate MetS subjects to continue with physically active lifestyle.

After 4 weeks of moderate intensity supervised aerobic training we already observed the decrease of body weight, body mass index and abdominal circumference. These findings could motivate subjects with MetS to continue their physical activity.

We also observed the lowering of LDL-Chol that was present in the 4-week training group of subjects with MetS. The tendencies of decrease in TG and increase in HDL-Chol were likewise observed but they did not reach statistical significance. Most investigators could find the decrease of TG and the increase of HDL-Chol as prevalent changes in MetS subjects after physical training [26–30,29]. It was shown that if elevated LDL-Chol was present prior to the study, intensive physical training was decreasing it [27,29]. In our study 46 subjects (81%) also had elevated LDL-Chol prior to the physical training programme. C-reactive protein is also directly related to manifestation of atherosclerosis [31]. We were able to show a statistically significant decrease of CRP after the 4-week aerobic training. Similar results in subjects with impaired glucose tolerance and obesity were presented by Andersson et al. [32].

The changes of arterial wall function and structure occurring prior to the development of obstructive atherosclerotic disease have been thoroughly studied over the last decades and are considered to be the precursors of developing overt CVD [33–35]. These changes can be assessed non-invasively by measuring the arterial stiffness and intima-media thickness. The golden standard for arterial stiffness evaluation is considered to be applanation tonometry performed by Sphygmocor, which allows to measure carotid-femoral PWV and carotid-radial PWV [15]. Sphygmocor-based measurements were chosen by us as the best validated method for evaluation of arterial function.

The assessment of arterial stiffness using Sphygmocor before and after 8 weeks of heart rate controlled physical training in 22 MetS patients was performed by Donley et al. [9]. The improvement of aortic and peripheral arterial stiffness parameters after exercising was shown in this study. We included a bigger cohort of subjects with MetS into our study and for the first time analysed the effect of a 4-week supervised aerobic exercise training on arterial wall parameters. We were able to show that the aortic stiffness (cfPWV) parameter is already improving after 4 weeks of supervised aerobic physical training. Other authors studied the effect of various modalities of physical activities – walking, jogging, incremental shuttle walk test – in metabolic, obese, diabetic subjects, and the results of these studies are contradictory [36–38].

Likewise, in our assessment of the carotid artery wall, we used the method superior to the one employed by the relevant studies published so far [39,40] – measurement of carotid artery distensibility and early structural change. Carotid artery intima-media thickening in μm was measured using the most advanced method of high-resolution echo-tracking by Artlab technology [16].

Conclusions

To conclude, in subjects with metabolic syndrome, a 4-week duration supervised aerobic exercise training (1) decreased body weight, body mass index and abdominal circumference, (2) improved lipid profile by lowering LDL-Chol and hsCRP, and (3) decreased aortic stiffness assessed by carotid-femoral pulse wave velocity; the latter seemed to be the most sensitive parameter for monitoring of arterial wall function under aerobic physical training.

These early occurring positive changes can motivate the patient with metabolic syndrome to start physical training with a short-duration supervised aerobic training programme and then continue it at home.

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