Haemodynamic parameters in postmenopausal women – beneficial effect of moderate continuous exercise training

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▌Abstract

Introduction and objective. Physical effort plays a positive role in reducing the risk of cardiovascular diseases. The aim of this study was to assess the cardiovascular status in postmenopausal women after several years of regular amateur training.
Materials and method. A total of 55 generally healthy females aged 50–70 years, of whom 38 were members of a senior exercise group and 17 comprised a control group, were enrolled in the study. Parameters of blood flow, vascular resistance, myocardial contractility and thoracic fluid content were measured in a 10-minute supine resting test by impedance cardiography. Thereafter, central blood pressure, augmentation index and pulse wave velocity were measured by applanation tonometry.
Results. Exercising women have a better outcome than the control group, when evaluated both with impedance cardiography and with applanation tonometry. They have a lower heart rate – HR (65.1 vs 71.5; p=0.033), higher blood flow (stroke index – SI, 58.6 vs 50.3; p=0.040), better myocardial contractility (acceleration index – ACI, 108.8 vs 88.1; p=0.027), higher preload (thoracic fluid content index – TFCI, 20.5 vs 18.1; p=0.002), lower afterload (systemic vascular resistance index – SVRI, 1972.9 vs 2110.5; p=0.026), lower central systolic blood pressure – cBPsys (119.0 vs 129.5; p=0.037), lower augmentation pressure – AP (10.3 vs 15.0; p=0.044) and lower pulse wave velocity – PWV (7.4 vs 8.4; p=0.001).
Conclusions. Regular moderate continuous aerobic exercise training has a beneficial impact on the cardiovascular system in postmenopausal women.

▌Key words

moderate continuous exercise training, females, impedance cardiography, applanation tonometry, physical activity of seniors

INTRODUCTION

Ageing, physical activity. The leading cause of death among adults is cardiovascular disease (CVD). While the mortality from CVD slightly decreases, its prevalence increases, which makes it an alarming challenge for the public health system [1]. Diabetes, metabolic syndrome, smoking, sedentary lifestyle, and advanced age are among the main risk factors [1, 2]. Therefore – and due to the demographic changes in advanced countries – ageing has become one of the leading subjects of research in various fields of study [3]. In 2000, there were 12.3% people aged over 65 in Poland, in 2005 there were 13.39% and, according to the prognosis of the Polish Central Statistical Office, there will be over 30% of elderly people in 2050 [4, 5]. These data reveal the scale of the problem of ageing societies. Physical activity was reported to significantly reduce the cardiovascular mortality by 35% [6]. Therefore, important fields of study are fitness level,

physical activity and the mobility of senior subjects, and their influence on health and quality of life [3, 7].

During the process of ageing, the cardiovascular system undergoes numerous changes, leading, among others, to impaired microcirculation, systemic pro-inflammatory state and increased risk of CVD. Arterial stiffness, vascular resistance and systolic blood pressure increase, while a decrease can be observed in cardiac output, maximal heart rate and autonomic reflexes [8, 9].

These changes can be prevented or reversed by the cheap and safe intervention of exercise training (ET). ET is being proven to be beneficial in both primary and secondary prevention of CVD and prolonging life expectancy. Therefore, it is a Class I recommendation in the guidelines of all leading cardiovascular societies [10, 11]. The beneficial effect of ET is dose dependent, meaning that some ET is better than none at all [12]. ET increases the intravascular shear stress, which leads to various molecular alterations, including increased NO bioavailability, mobilization of endothelial progenitor cells, and reduced oxidative stress. This results in improved cardiac [13, 14] and endothelial function, angiogenesis with collateral growth and reduced arterial stiffness [15], which reduces the

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risk for CVD [10]. Moderate continuous training (MCT) is a recommended training modality, as it is a well-established and safe protocol with well-demonstrated efficacy [16].

Impedance cardiography. Impedance cardiography (ICG) is an inexpensive, non-invasive technique that measures changes in transthoracic electric resistance (bioimpedance) in order to estimate phasic alternations in the blood flow [17, 18]. Validity, accuracy and repeatability of the results acquired by ICG have been confirmed in various comparative studies [19–21]. ICG is not only a useful tool for scientific studies but it also has prognostic value for hypertensive patients [22]. Although many ICG studies have been conducted on the immediate haemodynamic response of physical exercise [23–28], few have evaluated the long-term effects.

Applanation tonometry. Applanation tonometry (AT) provides data on both peripheral and central blood pressure. Central values refer to parameters calculated for the aorta with the use of data from the brachial artery [29–31].

OBJECTIVE

The aim of the study was to test the circulatory status of postmenopausal women by measuring haemodynamic indices after several years of regular amateur training.

MATERIALS AND METHOD

A total of 38 generally healthy exercising women and 17 non-exercising control subjects aged 50–70 years were recruited between December 2013 – May 2014. In the age ranges of 50–55, 56–60, 61–65 and 66–70 there were 13, 12, 9 and 4 patients, respectively. All subjects were members of a senior exercise group conducted in the Gdansk University of Physical Education and Sport. They participated in supervised, continuous aerobic endurance training at moderate intensities, one hour per session, twice a week (MCT) for 10 months in a year (except July and August). The participation was voluntary with an average attendance of 80%. 18 subjects exercised for 2–5 years, 14 for 10–15 years and 6 for 16–20 years. All the exercises were supervised by a first class trainer with 30 years of professional experience in sport and artistic gymnastics.

Inclusion criteria: female gender, age 50–70, good psychophysical condition; exclusion criteria: cardiovascular diseases other than arterial hypertension, severe chronic diseases. Other exclusion criteria were general contraindications against ICG examination: severe aortic regurgitation, intra-aortic balloon pump, severe hypertension, very low or high growth, severe obesity or severe malnutrition [19, 20].

The control group comprised 17 generally healthy non-exercising women with similar clinical characteristics.

Study protocol. After a standard physical examination all the patients underwent haemodynamic assessment with ICG and AT. Eight standard spot electrodes, a cuff, manometer and pulse oximeter were used. The NiccomoTM – Non Invasive Continuous Cardiac Output Monitor (Medis, Germany) and the Mobilograph (IEM, Germany) were applied.

Parameters of blood flow (stroke index – SI, cardiac index – CI), vascular resistance (systemic vascular resistance index – SVRI), myocardial contractility (pre-ejection period – PEP, left ventricle ejection time – LVET, velocity index – VI, acceleration index – ACI and Heather Index – HI) and thoracic fluid content index – TFCI, were recorded in a 10-minute supine resting test by impedance cardiography. Blood pressure was evaluated 5 times during the recording. Thereafter, central systolic and diastolic blood pressure (cBPsys and cBPdia, respectively), central pulse pressure – cPP, augmentation pressure – AP, augmentation index – AI, and pulse wave velocity – PWV, were measured by applanation tonometry. Both machines recorded heart rate – HR, systolic, diastolic and mean blood pressure (BPsys, BPdia and MAP, respectively).

The study was approved by the Ethical Committee of the Medical University of Gdansk and the participants signed an informed consent form.

Statistical analysis. Analysis was conducted by the Student t-test for independent samples, Mann-Whitney U test and Pearson's chi-square test. Clinical characteristics and haemodynamic parameters were compared between the groups. The normality of distribution was checked with Shapiro-Wilk W test. All statistical calculations were performed using Statistica 12.0 PL software package. A significance level α=0.05 was assumed.

RESULTS

Both groups had similar clinical characteristics. The only statistically significant difference was lower HR in the exercising group (Tab. 1).

Table 2 provides information about haemodynamic parameters in the exercising and control groups. Parameters representing vascular resistance, thoracic fluid content, blood flow and myocardial contractility differed significantly between the exercising and the non-exercising group. Exercise

Table 1. Characteristics of both groups.; Student t test marked with t (means provided). Mann-Whitney U test marked with U (medians provided), Pearson's chi-square test marked with χ (percentage provided). Bold indicates the p-value < 0.05

Parameter	Women with regular physical activity (n = 38)	Control group (n = 17)	p-value
Age [years]	59.4	62.4	0.066 t
Weight [kg]	64.0	65.0	0.334 U
Height [cm]	163.5	160.0	0.316 U
BMI [kg/m²]	24.1	24.9	0.300 t
BPsys [mmHg]	128.0	137.8	0.089 U
BPdia [mmHg]	83.2	87.4	0.244 U
MAP [mmHg]	103.7	110.3	0.099 U
HR [1/min]	**65.1**	**71.5**	**0.033 t**
Hypertension [%]	28.9	47.0	0.192 χ
Smoking [%]	10.5	17.6	0.421 χ

BMI – body mass index; BPsys – systolic blood pressure; BPdia – diastolic blood pressure; MAP – mean arterial pressure; HR – heart rate; blood pressure values measured by applanation tonometry at rest; only active smokers were counted

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Table 2. Haemodynamic parameters measured by impedance cardiography and applanation tonometry at rest in both groups. Student t test marked with t (means provided), Mann-Whitney U test marked with U (medians provided). Bold indicates p-value < 0.05

Parameter	Women with regular physical activity (n = 38)	Control group (n = 17)	p-value
Impedance cardiography			
TFCI [1/kOhm/m²]	**20.5**	**18.1**	**0.002** [t]
SI [ml/m²]	**58.6**	**50.3**	**0.040** [t]
CI [l/min/m²]	3.8	3.6	0.326 [t]
VI [1/1000/s]	68.6	56.8	0.428 [t]
ACI [1/100/s²]	**108.8**	**88.1**	**0.027** [t]
HI [Ohm/s²]	16.9	16.4	0.055 [t]
PEP [ms]	96.3	99.9	0.716 [t]
LVET [ms]	354.4	333.7	0.085 [U]
SVRI [dynes*sec*m²/cm⁵]	**1972.9**	**2110.5**	**0.026** [U]
PP [mmHg]	49.9	55.7	0.135 [t]
Applanation tonometry			
PP [mmHg]	44.8	50.4	0.135 [U]
cBPsys [mmHg]	**119.0**	**129.5**	**0.037** [U]
cBPdia [mmHg]	83.9	88.5	0.229 [U]
cPP [mmHg]	35.0	40.9	0.065 [U]
AP [mmHg]	**10.3**	**15.0**	**0.044** [U]
AI [%]	28.1	32.8	0.308 [U]
AI@75 [%]	22.2	30.4	0.066 [U]
PWV [m/s]	**7.4**	**8.4**	**0.001** [t]

TFCI – thoracic fluid content index; SI – stroke index; CI – cardiac index; VI – velocity index; ACI – accelerateon index; HI – Heather index; PEP – pre-ejection period; LVET – left ventricular ejection time; SVRI – systemic vascular resistance index; PP – pulse pressure; cBPsys – central systolic blood pressure; cBPdia – central diastolic blood pressure; cPP – central pulse pressure; AP – augmentation pressure; AI – augmentation index; AI@75 – AI standardized to a heart rate of 75 beats per minute; PWV – pulse wave velocity

lead to a decrease in SVRI and an increase in TFCI, SI and ACI. These findings were consistent with data obtained by AT, where a decrease in cBPsys, AP and PWV was observed.

DISCUSSION

Moderate continuous training (MCT) represents a protective factor for the cardiovascular system. Even though high intensity interval training (HIIT) might be a more effective training protocol for CVDs [32–34], its biggest drawback is the patient's adherence to treatment recommendations. Due to the lower intensity protocol, MCT is generally better accepted.

As is commonly known, aerobic exercise leads to a decrease in heart rate, which is confirmed by the data in the current study. This decrease in heart rate is compensated by an increase in SI, which is illustrated by maintained CI.

A decrease in SVRI was also observed, indicating a lower afterload in the exercising group. This positive effect has been shown by other authors and justifies the role of aerobic exercise training in antihypertensive therapy [35, 36].

The increase in ACI signifies the positive influence of exercise on the myocardial contractility.

In the current study, BPsys showed a noticeable trend but this was not significantly affected by the exercise (p-value

0.079). This finding might be explained by the small size of the examined population. A repetition with a bigger sample would probably reveal the expected effect.

Even though there are no statistically significant differences in blood pressure parameters measured by ICG, noticeable changes can be observed in AT, whereas cBPsys, AP and PWV are significantly lower in the exercising group. These findings show a positive effect of physical activity on the cardiovascular system and emphasizes that AT reveals early differences in cardiovascular haemodynamics (central parameters, e.g. cBPsys, AP, PWV) between patients with similar outcome in *classic* parameters.

The presented data show a significant increase in TFCI, which represents the preload. Due to the Frank-Starling law, this increase in the preload causes an increase in SI, as described elsewhere [37, 38]. With increasing end diastolic volume, the tension in the ventricle wall, and in consequence the sensitivity to calcium of the contractile proteins rise, physiologically resulting in a higher stroke index [39]. It is worth mentioning that all the measurements of preload were within the physiological ranges.

The current study has some limitations. Since the study group was small, it should be treated as a preliminary report. The study has described some tendencies observed which did not reach statistical significance. It is conceivable that the strength of these findings would be improved by increasing the size of the study group. The observations were restricted to postmenopausal women and should not be transferred to the general population. Both analyzed groups had similar characteristics; however, the presented observations are limited by lack of randomization.

CONCLUSIONS

Moderate continuous aerobic exercise training has a positive effect on haemodynamic status in postmenopausal women, which can be measured by impedance cardiography and applanation tonometry.

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