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Heart rate recovery as a sensitive indicator of physical activity changes in perimenopausal and postmenopausal women

Tempo restytucji częstości skurczów serca jako czuły wskaźnik zmian stopnia aktywności fizycznej u kobiet w wieku około i pomenopauzalnym

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Key words
heart rate, heart rate recovery, physical activity in the elderly

Summary
Background: Heart rate recovery (HRR), which is defined as the rate of heart rate decline after cessation of exercise, is an important indicator of exercise tolerance. The aim of this study was to investigate the effect of a 4-month moderate reduction in physical activity on pre-exercise and exercise heart rate (HR) as well as HRR after exercise cessation in perimenopausal and postmenopausal women.
Material and methods: 10 physically active females, 62.5±3.0 years old, participated in this study. They performed an 8-min constant power output (~50W) cycling exercise at an intensity corresponding to about 65% of maximal heart rate. Heart rate was measured continuously starting from 1 minute before exercise, during the exercise test and 3 min after exercise cessation. Furthermore, before and after exercise, blood pressure (BP) and tympanic temperature (T_t) were measured. The exercise test was performed twice, before and after a 4-month reduction in physical activity.
Results: 4 months of the slight reduction in physical activity (by ~16%) did not cause any changes in pre-exercise and exercise HR, however, significantly higher HR during the 1st min after exercise ($p=0.03$), as well slower HRR ($p=0.03$), were reported. No effects of the reduction in physical activity were observed in resting and post-exercise BP and T_t.
Conclusion: Even a slight reduction in physical activity is accompanied by a lower rate of HRR, which indicates a decrease in exercise tolerance. These results indicate that HRR is a sensitive indicator of physical capacity also in peri- and postmenopausal women, since the changes in HRR in response to physical activity level occur earlier than changes in pre-exercise and exercise heart rate.

Słowa kluczowe
częstość skurczów serca, tempo restytucji częstości skurczów serca, aktywność fizyczna osób starszych

Streszczenie
Wstęp: Szybkość spadku częstości skurczów serca po zakończonym wysiłku, czyli tempo restytucji częstości skurczów serca (HRR) jest ważnym wskaźnikiem tolerancji wysiłku. Celem niniejszej pracy było zbadanie wpływu umiarkowanej redukcji aktywności fizycznej na przedwysiłkową, wysiłkową częstość skurczów serca (HR) oraz na przebieg HRR po wysiłku w grupie kobiet w wieku około- i pomenopauzalnym.
Materiał i metody: W badaniach wzięło udział dziesięć aktywnych fizycznie kobiet w wieku 62.5±3.0 lat. Badane wykonywały 8-minutowy test wysiłkowy na cykloergometrze ze stałą intensywnością (~50W) odpowiadającą ~65% maksymalnej częstości skurczów serca. Częstość skurczów serca mierzono w sposób ciągły, począwszy od 1 minuty przed rozpoczęciem testu, w cza-

The individual division of this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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sie jego trwania oraz przez 3 minuty od jego zakończenia. Przed rozpoczęciem testu wysiłkowego oraz tuż po jego zakończeniu wykonano pomiar ciśnienia tętniczego krwi (BP) oraz temperatury tympanalnej (T_t). Test wysiłkowy wykonano dwukrotnie przed i po 4-miesięcznym okresie zmniejszenia aktywności fizycznej.
Wyniki: 4-miesięczny okres niewielkiego zmniejszenia aktywności fizycznej (o około ~16%) nie wywołał istotnych zmian w przedwysiłkowym i wysiłkowym HR, jednakże zaobserwowano istotnie wyższe HR w 1 minucie po zakończeniu wysiłku ($p=0.03$), jak i wolniejsze tempo HRR ($p=0.03$). Redukcja obciążeń treningowych nie wywołała zmian w spoczynkowych i powysiłkowych wielkościach BP i T_t.
Wnioski: Nawet niewielka redukcja aktywności fizycznej prowadzi do spadku tempa restytucji częstości skurczów serca co wskazuje na pogorszenie tolerancji wysiłku. Wyniki te dowodzą, że HRR jest czułym wskaźnikiem wydolności fizycznej również u kobiet w wieku około- i pomenopauzalnym, gdyż jego zmiana w odpowiedzi na zmianę poziomu aktywności fizycznej pojawia się wcześniej niż zmiany w przedwysiłkowej i wysiłkowej częstości skurczów serca.

INTRODUCTION

Cardiovascular disease is currently one of the most common causes of mortality apart from cancer[1]. As it has been shown, regular physical activity exerts a cardioprotective effect on the circulatory system[2] by reducing risk factors such as hypertension, obesity, insulin resistance[3], and by improving functioning of the circulatory system[4]. On the other hand, lack of physical activity or its cessation increases the risk of civilization ailments, including cardiovascular diseases[5]. In elder people, regular physical activity induces many beneficial health effects, i.e. it, among others, contributes to improving the decreasing cardiovascular fitness with age[6]. As a result of regular physical activity, along with an increase in physical fitness (increase in VO_{2peak}), reduction occurs in the heart rate in response to a given load with increased left ventricular filling time, increased venous return, which leads to an increase in stroke volume of the heart[7]. The increase in stroke volume is one of the benefits of regular exercises undertaken by elder individuals[7]. In addition, regular exercise in the elderly increases the sensitivity of β-adrenergic receptors to noradrenaline in the aging process[8]. An important aspect of undertaking regular physical activity is the need to monitor the exercise intensity, so that the applied exercise is well-tolerated and safe for older people. Incorrect choice of training workloads can worsen the health status of the training participants , especially those at an older age[9]. The most widespread, non-invasive indicators of cardiovascular system assessment used in sports medicine, sports and rehabilitation, cardiological in particular, include the measurement of heart rate (HR) during exercise[9-12]. As it is known, the beginning of exercise is associated with the acceleration of HR, and its cessation, with a decrease in HR[13]. Although the mechanism of regulating heart rate during exercise and after exercise is not fully understood[14,15], the central nervous system reflex (central command), ergoreceptor reflex in working muscles (metaboreflex) and the reflex with arterial baroreceptors are considered significant in this process[14,15]. Measurement of heart rate is a basic, simple indicator found in the assessment of physical performance[11], as well as in monitoring training loads[11,16]. It should be emphasized that an important, although often overlooked, physical performance parameter based on HR measurement is the rate of decline in heart rate after exercise, i.e. so-called heart rate recovery (HRR)[17-19]. It is believed that HRR, as well as heart rate variability (HRV), describing the balance between sympathetic and parasympathetic innervation of the heart[20,21]. Variability of sinus rhythm reflects the tonic effect of the autonomic nervous system on heart function, whereas HRR is the result of the return of vagus nerve activity after cessation of physical exercise[21]. Heart rate recovery depends on the level of training[20-22], exercise intensity [13,23] or age[19,24]. It is known that regular physical activity leads to acceleration in HRR[25,26], hence, faster HRR is observed in trained persons in comparison to non-trained ones[18,20]. The higher the exercise intensity, the faster the heart rate recovery[13,23]. In turn, along with increasing the duration of physical exertion, the longer the heart rate recovery time[13,19]. Similarly, in a group of, i.e. cardiac patients following myocardial infarction[27] or heart failure[27,28], subjected to a systematic cardiac rehabilitation programme, acceleration of HRR after the period of participation in the rehabilitation programme was observed[27,28]. With age, there is deterioration in physical performance and a reduction in HRR[24]. The slower HRR observed in older people results, among others, from reduced activity of the parasympathetic system appearing in the aging process[24,29]. Delayed HRR is associated with an increased risk of cardiovascular death in both healthy people[30-32] as well as in ill-patients[17,33].

STUDY AIM

The aim of this study was to examine the impact of a 4-month period of reduced regular physical activity on pre-exercise, exercise-induced and post-exercise heart rate and heart rate recovery in a group of 10 physically active perimenopausal and postmenopausal women, and in particular, to answer the following questions:

1. Does a 4-month period of slight decrease in physical activity influence the increase in pre-exercise, exercise-induced and post-exercise heart rate in the examined group of women?
2. Does the change in the post-exercise heart rate precede changes in the pre-exercise and exercise-induced heart rate in the studied group of women?
3. Can the post-exercise heart rate, including the rate of HRR, be used to monitor exercise intensity in older people, including perimenopausal and postmenopausal women?

MATERIAL AND METHODS

Study group

10 healthy, physically active women aged 51 to 81 participated in the study (Table 1). The subjects were acquainted with the research methodology and qualified for participation in the study after completing the questionnaire (Physical Activity Readiness Questionnaire PAR-Q questionnaire)[34], conducting the initial medical examination and after providing written consent to participate in the trial. 2 women were excluded from the pre-qualified patients due to increased resting blood pressure. The group of women was also interviewed regarding the type, frequency and duration of physical activity. 8 women from the study group attended regular physical activity classes for the elderly conducted at the University of the Third Age (~1.5-2 hours per week) and declared performing additional physical activity alone, a total of approx. 5 hours a week (moderate intensity efforts including marches, cycling, swimming), and the remaining 2 participants exercised regularly for a total of about 7 hours per week (including cycling, swimming, marches). On the basis of data from the interview about the time spent on physical activity per week, for each of the studied women, a weekly amount of energy expenditure was calculated using the formula:

Kilocalories = MET × body mass [kg] × time [hour][35] (*equation 1*)

Anthropometric measurements

Body mass and percentage of adipose tissue (bioimpedance method) were measured using the TANITA scales (UM018, TANITA Europe GmbH). Waist and hip circumferences were measured with a centimetre measuring tape to the nearest 0.5 cm. The measurements were performed twice before (Pre) and after (Post) the 4-month period of reducing regular physical activity.

Exercise test

The examined women performed 8-minute exercise tests of constant intensity at a stable, controlled speed of 60 revolutions·min^{-1} about 2 hours after a light meal. The exercise tests were performed on a cycloergometer (DAUM electronic CARDIO PRO, Germany) allowing for the control of the generated power (W). 2 exercise tests were performed: the first just after completing the 8-month period of regular physical activity, and before the 4-month period of reduced physical activity, i.e. in June (Test Pre), and the second after the 4-month period of reducing regular physical activity, i.e. in September (Test Post) (Figure 1).

In both exercise tests, during the test performed before and after the 4-month period of reduced physical activity (Test Pre and Test Post), the examined women performed exercise with the same individually designated amount of power output. The amount of power output was chosen so that the exercise-induced heart rate ranged from 60-70% of maximal heart rate (HR_{max}), which corresponded to the load on the cycloergometer from 50 to 65 W.

Heart rate frequency

The registration of heart rate (POLAR EleCtro S810, Finland) was always started just before the exercise test (about 1 minute before beginning the test), and was continued during the 8-minute effort and 3 minutes after its completion. The HR measurement was carried out with 5-second intervals. The HR value from each minute of the effort is presented as the average HR value from the last 15 seconds for every minute of effort. The HR measurement during the exercise test was performed twice, both before and after the 4-month period of reduced physical activity. The course of changes in the frequency of heart rate during the effort performed before the 4-month period of reduced physical activity for one of the examined women is shown in Figure 2.

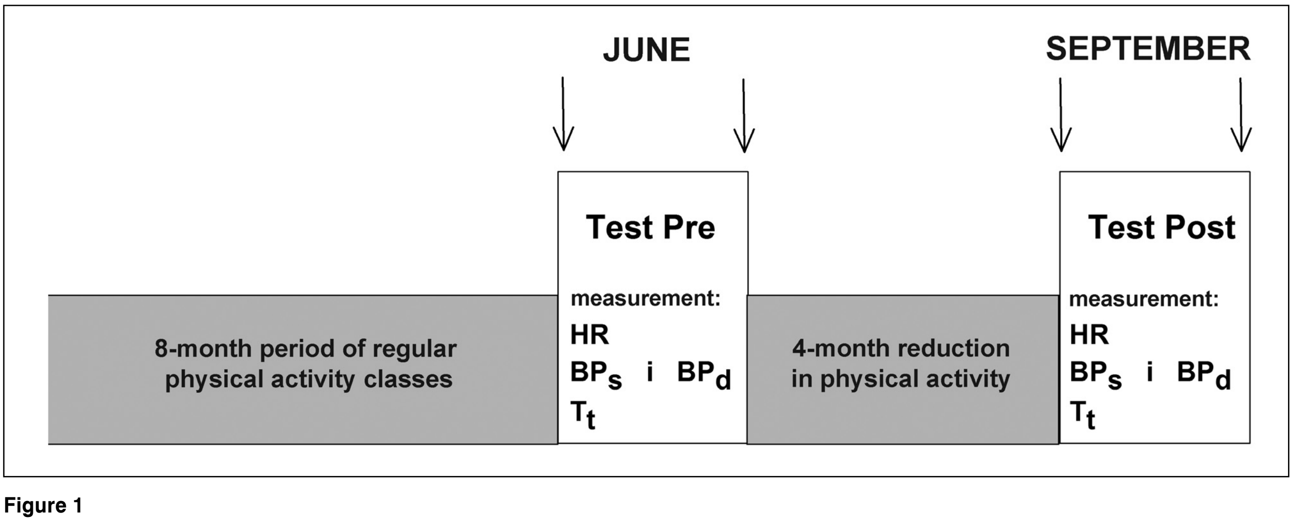

Figure 1

Research design including: a) 8-month period of regular physical activity at the Third Age University; b) exercise test performed after completing the 8-month period of regular physical activity (Test Pre); c) 4-month reduction in physical activity; d) exercise test performed after the 4-month period of reduction in physical activity (Test Post)

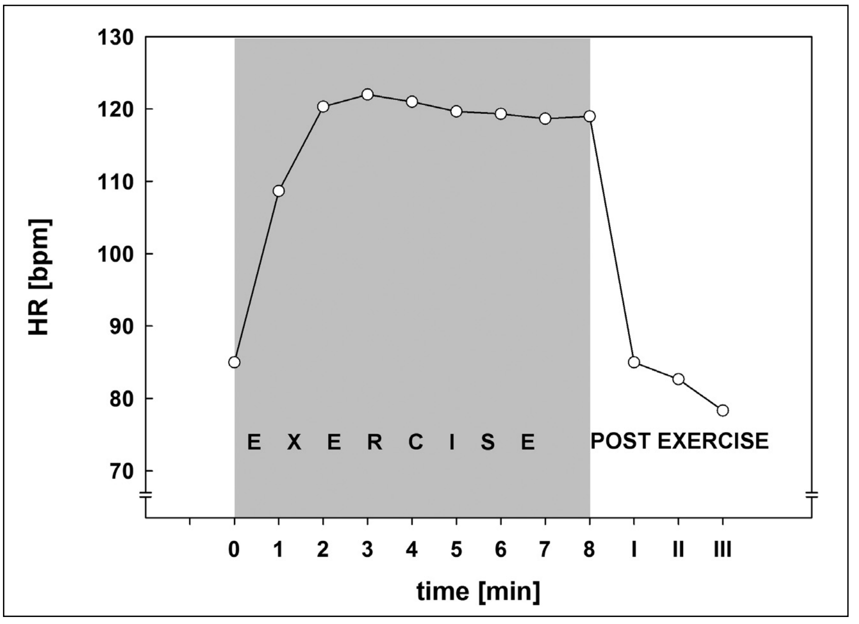

Figure 2

Heart rate during exercise performed by one of the individuals from the studied group of women

Blood pressure measurements

In each of the subjects, systolic (BP_s) and diastolic blood pressure (BP_d) were measured before and after the exercise test using a blood pressure measuring device with an individually selected cuff width (WelchAllyn, New York, USA). The measurement of blood pressure was performed both before and after the 4-month period of decreased physical activity.

Tympanic temperature measurements

Tympanic temperature (T_t) measurements were performed during rest as well as before and after the exercise test (Braun 6020 Kronberg, Germany). The measurement of tympanic temperature was performed both before and after the 4-month period of decreased physical activity.

Analysis of research results

Body mass index (BMI) and waist-to-hip ratio (WHR)
For each of the studied women, body mass index [kg·m^{-2}] = body mass [kg] × body height^{-2} [m] (*equation 2*) and the ratio of waist-to-hip circumference, WHR = waist circumference [cm] × hip circumference^{-1} [cm] (*equation 3*) were calculated.

Estimated maximal heart rate (HR_{max}), heart rate during exercise (HR_{ex}) post-exercise heart rate (HR_{postex}) and heart rate recovery (HRR)
For each of the examined women, HR_{max} was estimated based on the Tanaka formula[10]: HR_{max} = 208 - (0.7 age in years) (*equation 4*). The heart rate during exercise (HR_{ex}) is presented as the average HR value from thesteady-state period of exercise , i.e. from the 5th, 6th, 7th and 8th min of exercise. Heart rate after exercise (HR_{postex}) is shown as the mean HR value from 3 minutes after physical exercise (Figure 2). In addition, for each of the studied women, the following were calculated: a) the difference in the heart rate heart rate measured during exercise (HR_{ex}) and HR measured just before beginning the exercise test (HR_{rest}) ($\Delta_1 HR = HR_{ex} - HR_{rest}$); b) heart rate recovery (HRR) as the difference between post-exercise heart rate (HR_{postex}) and the heart rate recorded just before beginning physical exercise ($HRR = HR_{postex} - HR_{rest}$).

Statistical analysis
For all of the presented parameters, the following descriptive statistics were calculated: minimum and maximum value (min ÷ max), arithmetic mean and standard error ($\bar{x}$ ± SEM). Due to the small number of participants in the studied group (n = 10), the significance of differences in mean values in two groups of related variables was checked using the non-parametric Wilcoxon test. Analysis of changes in heart rate during exercise performed before and after the 4-month period of decreased regular physical activity was done using analysis of variance (ANOVA with repeated measurements). Significance of differences was at the level of p = 0.05. Statistical analysis was performed using the STATISTICA 9.0 programme.

RESULTS

Characteristics of the study participants

The basic characteristics of the studied group of women $\bar{x}$ ±SEM: age 62.5±3.0 years; height 161.2±0.02 cm) are shown in Table 1.

In the studied group of women (n = 10), the number of hours devoted to physical activity during the period of regular physical activity classes (8 months) was 6.2±1.1 hours per week, while during the 4-month period of reducing regular physical activity, it was about 16% lower (p = 0.64, 5.2±1.8 hours per week). The average calculated amount of energy devoted to physical activity during the period of regular physical activity (8 months) totalled approx. 1,574 kcal·week^{-1} and was about 12% higher than during the 4-month period of reduced regular physical activity, on average (p = 0.88; 1,401 kcal·week^{-1}). The 4-month period of reduced physical activity did not significantly affect body mass, percentage of body fat, BMI and WHR (p> 0.05; Table 1).

The effect of single bout, constant power output, moderate-intensity exercise on heart rate, blood pressure and tympanic temperature

Exercise-induced changes in heart rate and blood pressure were discussed on the basis of the exercise

Table 1

Selected anthropometric parameters in the studied group of women (n = 10) before (Pre) and after (Post) the period of reduction in physical activity

Anthropometric parameters	Pre		Post		p
	x̄ ± SEM	min ÷ max	x̄ ± SEM	min ÷ max	
Body mass [kg]	69.3 ± 3.0	56.2 ÷ 89.2	69.2 ± 3.1	56.0 ÷ 89.1	0.58
Body fat content [%]	35.2 ± 1.2	30.5 ÷ 43.7	36.1 ± 1.4	30.2 ÷ 45.0	0.10
BMI [kg·m^{-2}]	26.6 ± 0.9	22.7 ÷ 32.4	26.6 ± 0.9	22.5 ÷ 32.3	0.65
WHR	0.87 ± 0.02	0.8 ÷ 0.95	0.86 ± 0.02	0.78 ÷ 0.92	0.33

BMI – body mass index; WHR – waist to hip ratio; SEM – standard error

test performed just after completing regular physical activity in the studied group of women, and before the 4-month period of reduction in physical activity (Test Pre).

Heart rate frequency during moderate-intensity exercise

In the examined group of women, heart rate during exercise (HR_{ex}) increased by approx. 38% in relation to HR measured just before beginning the test (HR_{rest}) ($p = 0.005$), and was, on average, 109±3.7 bpm.

The average heart rate measured within 3 minutes after completion of exercise (HR_{postex}) was about 23% ($p = 0.005$) lower than the value measured during exercise (HR_{ex}) (Figure 3).

Blood pressure and tympanic temperature during moderate-intensity exercise

Table 2 presents the changes in systolic and diastolic blood pressure as well as tympanic temperature for the studied group of women.

Systolic blood pressure (BP_s) at the end of exercise was about 12% higher than ($p = 0.005$) BP_s at rest. The diastolic blood pressure did not change significantly during the exercise in relation to resting values ($p = 0.79$; Table 2). In the studied group of women, no changes ($p > 0.05$) in tympanic temperature (T_r) recorded after the exercise test in relation to resting values were observed (Table 2).

Influence of the 4-month period of reduction in regular physical activity on pre-exercise, exercise-induced and post-exercise heart rate

Figure 4A shows the average heart rate before and after the 4-month period of reduction in regular physical activity among women (n = 10). As a result of a slight decrease in the weekly time (i.e. about 16%) devoted to physical activity, there were no changes in the heart rate measured just before beginning the exercise test ($p = 0.72$; Figure 4B) or in the heart rate recorded during exercise ($p = 0.94$, Figure 4C). In turn, the frequency of heart rate registered during the first minute following exercise (HR_{1min}) performed after the 4-month period of decreased physical activity (Test Post) was significantly higher ($p = 0.03$) than the HR measured during the first minute after completing the exercise before that period (Figure 4D).

Moreover, in the examined group of women, the difference between the exercise-induced heart rate and HR in the first minute after cessation of exercise was, on average, 21±2.6 bpm in the Pre Test and was significantly higher ($p = 0.047$) than in the test performed after the 4-month period of reduced physical activity (15±1.9 bpm).

The exercise-induced increase in heart rate versus resting state (Δ_1HR) in the Post Test was approximately 40%, and did not differ significantly ($p = 0.28$) from the increase in HR during exercise performed in the Pre Test (by about 38%; Figure 5A).

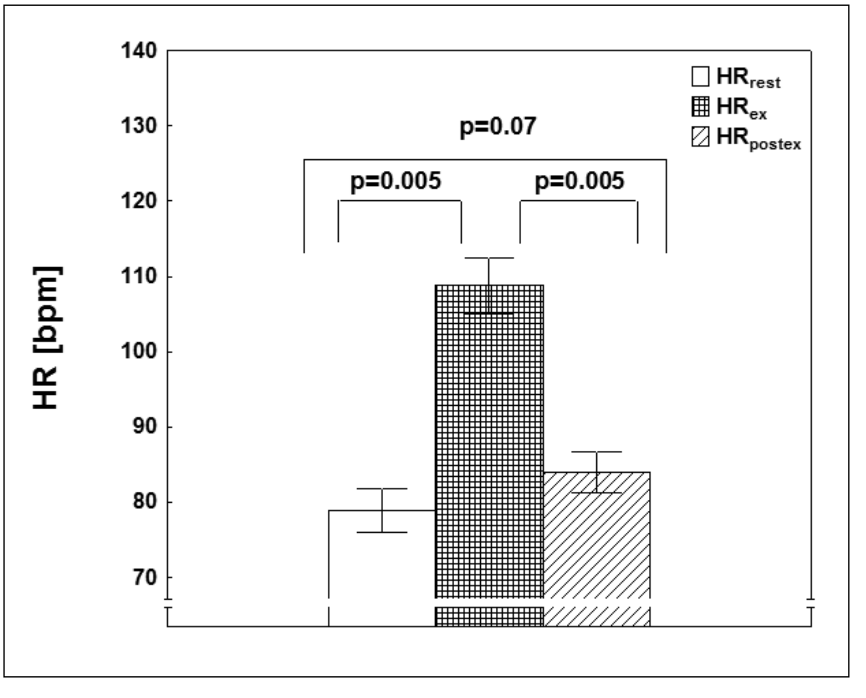

Figure 3

The effect of constant power output, moderate intensity exercise performed before the 4-month reduction in physical activity (Test Pre) on heart rate measured just before exercise test (HR_{rest}), exercise heart rate (HR_{ex}) and post-exercise heart rate (HR_{postex})

Table 2

Systolic (BP_s) and diastolic (BP_d) blood pressure, tympanic temperature (T_t) at rest and at the end of the exercise test, before (Pre) and after (Post) the 4-month reduction in physical activity

	Pre	Post	*p*
Blood pressure [mmHg]			
BP_s at rest	121 ± 4	120 ± 4	0.73
BP_s after test	135 ± 4*	135 ± 3*	0.83
BP_d at rest	71 ± 2	71 ± 3	0.83
BP_d after test	71 ± 3	69 ± 2	0.3
Tympanic temperatur [°C]			
T_t at rest	36.9 ± 0.1	36.7 ± 0.2	0.24
T_t after test	36.9 ± 0.1	36.9 ± 0.1	0.83

*p < 0.05 significant difference between value measured at rest and just after exercise

The effect of the 4-month period of reduced physical activity on blood pressure and tympanic temperature

The 4-month period of reduction in regular physical activity did not lead to changes in resting or post-exercise values of systolic and diastolic blood pressure or tympanic temperature ($p > 0.05$; Table 2).

DISCUSSION

In the present study, it was shown that in the group of women aged 50-80, the 4-month period of slight decrease in physical activity (about ~ 16%, $p = 0.64$) did not induce significant changes in pre-exercise heart rate (Figure 4B) or heart rate recorded during exercise (Figure 4C). Nonetheless, the reduction of physical activity (by approx. 16%) caused significant changes in post-exercise heart rate; namely, a higher heart rate was observed 1 minute after completion of exercise ($p = 0.03$; Figure 4D), as well as slower heart rate recovery ($p = 0.03$; Figure 5B). In addition, it was shown that the reduction of physical activity in the 4-month period did not cause significant changes in resting or post-exercise blood pressure values or tympanic temperature (Table 2). In the described period, no significant changes in body mass or percentage of adipose tissue were observed in the studied group of women (Table 1).

The effects of a single bout, constant power output, moderate-intensity exercise on heart rate, blood pressure and tympanic temperature in the studied group of women (n = 10)

In the studied group of perimenopausal and postmenopausal women, the constant power output exercise test (about 53±4 W) performed before the 4-month period of physical activity reduction led to an increase in heart rate by about 40% (Figure 3) as well as to an increase in systolic blood pressure (by approx. 12%) compared to the pre-exercise values of these parameters in the absence of changes in diastolic blood pressure (Table 2). Similar changes (heart rate and blood pressure) in response to exercise of the same intensity were observed in the exercise test performed after the 4-month period of decreased physical activity (see: Results). The exercise-induced changes in blood pressure and heart rate registered in this study do not differ from the results obtained by other authors regarding moderate-intensity efforts for middle-aged and elderly patients[36, 37]. Additionally, the applied exercise did not cause changes in tympanic temperature (Table 2). These results indicate that in the studied group of women, the applied exercise did not constitute a significant burden for the body.

The effects of the 4-month period of reduced physical activity on heart rate

Regular physical activity decreases resting heart rate[13,38], the frequency of contractions recorded in the case of a given load[13,38], and leads to acceleration of HRR[38,39]. In turn, the reduction or discontinuation of regular physical activity leads to an increase in heart rate recorded at rest, during exercised and after cessation of exercise (including slowdown in HRR)[22,40]. It is believed that the cause of changes in the heart rate after cessation of regular physical activity is the reduction in the increased parasympathetic activity induced by regular training[22]. In addition, a higher increase in catecholamine concentrations during exercise[22,38], as well as an exercise-induced increase in the concentration of metabolites such as hydrogen ions and potassium ions[22,38] also have an impact on higher exercise-induced heart rate after discontinuing regular physical activity. In this study, in the group of perimenopausal and postmenopausal women, the 4-month period of reducing physical activity by about 16% did not induce changes in resting heart rate (Figure 4B) or heart rate recorded during exercise (Figure 4C). In studies by other authors, there was an increase in heart rate measured at rest and during exercise after discontinuation of regular physical activity. Hardman and Hudson[41], in a group of middle-aged women (about 47 years old), observed a higher heart rate during exercise performed 3 months after completing a 12-week walking training programmed[41]. Similarly, Giada et al.[42] demonstrated in a group of elder (about 55 years of age), physically active men an increase in resting HR by about 12% and greater heart rate recorded during exercise by about 6% after a 2-month period of lack of reg-

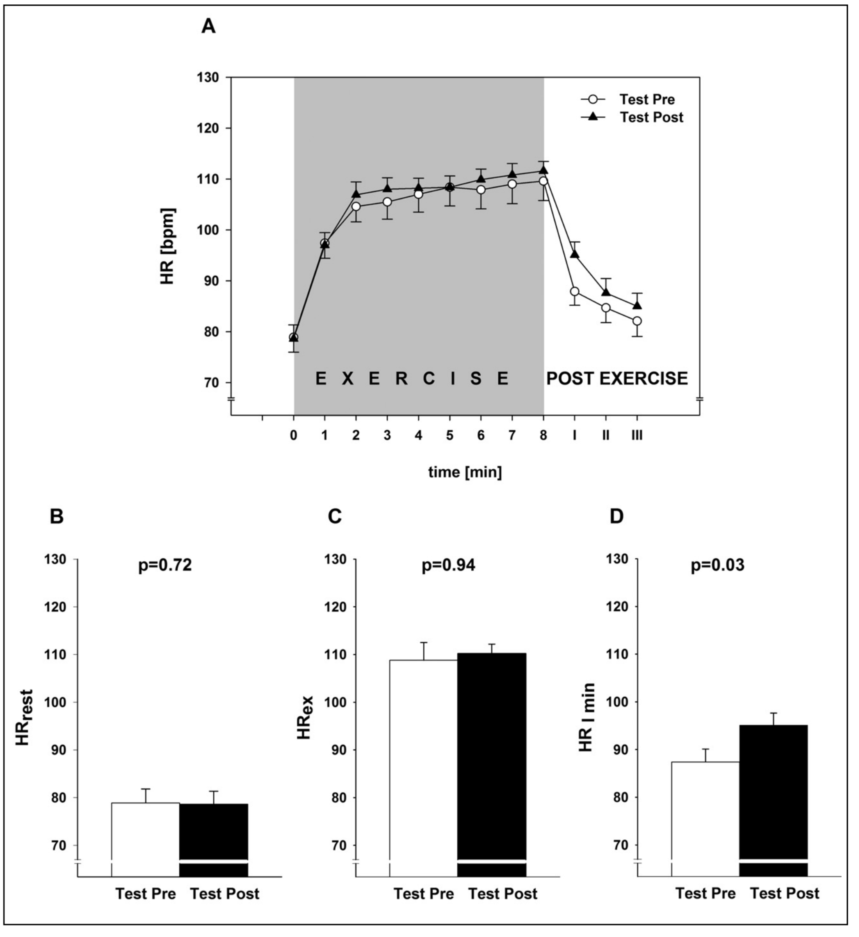

Figure 4 A-D

Heart rate during exercise performed before (-○-) and after (-▲-) 4-month reduction in physical activity in the studied group (n = 10) (panel A). The effect of 4-month reduction in physical activity on heart rate measured just before exercise (HR_{rest}, panel B), heart rate during exercise (HR_{ex}, panel C) and heart rate measured during the 1st min after exercise cessation (HR_{Imin}, panel D)

ular physical activity compared to the values of the mentioned parameters before the period of discontinuing training[42]. Lack of changes in resting heart rate (Figure 4B) and heart rate measured during exercise (Figure 4C) observed in the studied group of women may result from the fact that in the analysed period (4-month period of reducing regular physical activity), the decrease in physical activity was small and was only about 16% (i.e. about 1 hour less a week), because the surveyed women implemented their own physical activity programmes. Despite the lack of changes in heart rate measured at rest and during exercise changes in post-exercise heart rate were observed in response to the 4-month reduction in physical activity. Namely, the heart rate recorded during the first minute after ending exercise in the exercise test performed after the period of reduced physical activity was significantly higher (by approx. 7%, $p = 0.03$, Figure 4D) compared to the HR_{Imin} measurement before this period. It should be noted that the return of heart rate to resting values is mainly caused by the reactivation of the parasympathetic system and the reduction of the activity of the sympathetic system after the completion of exercise[13,14,22,25]. The initial, rapid decrease in heart rate after exercise (the first 60 seconds) primarily depends on the reactivation of the parasympathetic system[11,13,43], as demonstrated in research with parasympathetic blockers[38,40]. In turn, the second, slower phase of HRR is a consequence of the cooperation of the parasympathetic and sympathetic systems, and on the one hand, results from the reactivation of the parasympathetic system and on the other, from the still active sympathetic system stimulated by the metabolites produced during the effort, i.e. hydrogen ions, potassium ions, adenosine, bradykinin, phosphates, arachidonic acid metabolites[11,13,43]. In the post-exercise period, the reflex of metaboreceptors along with the slowly removed circulating catecholamines in the blood reflexively strengthen the activity of the sympathetic nervous system[11,13,38]. This persistent, slower decline in the frequency of heart rate after exercise protects the body against post-exercise fainting, as it prevents the sudden fall in blood pressure resulting from peripheral vasodilation during exercise[13]. One of the important parameters assessing the rapid phase of reactivation of the parasympathetic system in the post-exercise period is the size of the decrease in the heart rate during the first minute after completing physical exercise[17,33]. The results of the study show that the decrease in the heart rate in the first minute after cessation of exercise in healthy people should be ~15-20 bpm·min^{-1} compared to the value obtained during exercise[19,30,31]. The decrease in HR in the first minute after exercise less than 12 bpm·min^{-1} is associated with an increased risk of cardiovascular-related death[17,19].

In this research, the HR decrease during the first minute after the cessation of exercise, compared to the exercise-induced HR, was 21 bpm, and 15 bpm, respectively for the exercise test performed before and after the 4-month reduction in physical activity ($p = 0.047$). These values indicate proper reactivation of the post-exercise parasympathetic system[30,31] in both exercise tests (Test Pre and Test Post), however, they further indicate delayed reactivation of the parasympathetic system in the exercise test performed after the 4-month period of physical activity, which indicates deterioration of physical capacity[21,25]. In the present study, in addition to the evaluation of heart rate in the first minute after the completion of exercise (Figure 4D), heart rate recovery was tested during 3 minutes from the completion of the

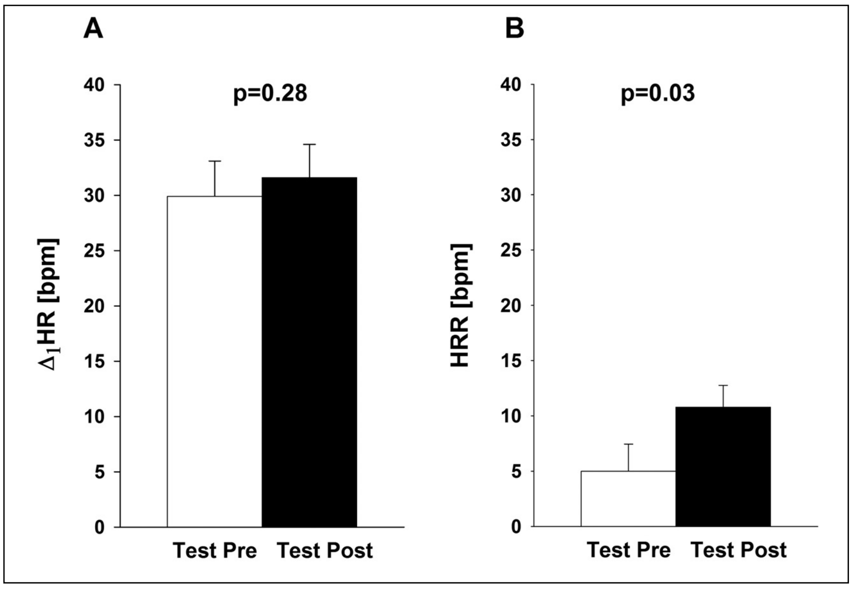

Figure 5

The effect of 4-month reduction in physical activity on differences between exercise (HR_{ex}) and pre-exercise (HR_{rest}) heart rate (Δ_1HR, panel A); post-exercise (HR_{postex}) and pre-exercise (HR_{rest}) heart rate (HRR, panel B)

effort compared to the values recorded before activity (Figure 5B) in the exercise test taken both before and after the 4-month period of physical activity reduction. In the examined group of women at perimenopausal and postmenopausal age, after the 4-month period of reduced physical activity, reduced HRR rate was observed (Figure 5B) which may indicate worsening of the interaction of the parasympathetic-sympathetic system after a period of reduced physical activity[11,13,43]. The slower rate of HRR (Figure 5B), despite the absence of the changes in heart rate recorded at rest (Figure 4B) and during exercise (Figure 4C) reflect a decrease in physical performance. This is consistent with the reports of other authors, pointing to the fact that changes in post-exercise heart rate occur much earlier than changes in resting or heart rate recorded during exercise [25] in response e.g. to increasing or reducing training loads[25].

CONCLUSIONS

1. The 4-month period of slight decrease in physical activity in the studied group of perimenopausal and postmenopausal women does not affect the heart rate measured at rest and during exercise however, it leads to an increase in the post-exercise HR.
2. The post-exercise heart rate is a sensitive indicator of even a small reduction in physical activity, as its changes appear earlier than changes in the heart rate recorded at rest and during exercise.
3. Recording and analysing the post-exercise HR, including the rate of HRR, may be used to monitor physical training or rehabilitation (e.g. cardiac) in older people also in perimenopausal and postmenopausal women.

Conflict of interest: none

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