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# HEALTH IMPACT OF TRAINING INTENSITY IN OLDER INDIVIDUALS

## UTJECAJ INTENZITETA TRENINGA NA ZDRAVLJE STARIJIH OSOBA

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SAŽETAK

S godinama života sposobnosti održavanja zadane tjelesne aktivnosti na određenoj razini postaju sve slabije. Ovo je djelomično vezano uz smanjenje sposobnosti kardiorespiracijskog kapaciteta. Cilj ovoga rad bio je utvrditi kako jednostavna dnevna aktivnost kao što je hodanje može poboljšati sposobnost cjelokupnog kardiorespiracijskog sustava. Uzorak ispitanika bio je sastavljen od 42 zdrave žene u dobi od 58 godina koje su bile prekomjerno teške do umjereno gojazne i u postmenopauzi. Njihov trening se sastojao od hodanja 4.83 km dnevno tijekom 15 tjedana sa zadanim intenzitetom. Prije i poslije petnaestodnevnog tretmana mjerene su sljedeće varijable: visina i masa tijela, indeks tjelesne mase, kožni nabori i opsezi na standardiziranim mjestima da bi se mogao izračunati postotak tjelesne mase prema Jackson, Pollock i Ward-u, ventilacijski prag, frekvencija srca i arterijski krvni tlak.

Istraživanje je omogućilo nekoliko zaključaka. Općenito zaključeno je da je 15 tjedana hodanja dovoljno da poboljša aerobni kapacitet te da je poboljšanje proporcionalno intenzitetu treninga. Nadalje, uočeno je da trening ima višestruko djelovanje na kardiorespiracijske parametre. Kod žena je uočena tendencija sniženja sistoličkog i dijastoličkog tlaka kao i frekvencije srca.

*Ključne riječi:* odrasla populacija, opterećenja, zdravlje

ABSTRACT

As we age, our capacity for sustained and intense physical exertion declines. This partly represents a decline in cardio-respiratory capacity. The aim of this study was to examine the extent to which a simple prototypic form of physical activity, walking, can improve components of cardio-respiratory function in aging individuals. Postmenopausal women were selected for study because of their demographic prevalence, general paucity of information on the effects of training on their cardio-respiratory function, and their increased risk of CHD following estradiol decline. Walking was selected because it is the principal physical means of human locomotion and dynamically engages large muscle groups. It also is universally accessible without the necessity for specialized equipment or facilities.

Subjects were 42 generally healthy overweight to moderately obese postmenopausal women aged 58. Training consisted of walking 4.83 km/day five days a week for 15 weeks at an assigned intensity. Before the start, and after 15 weeks of training, the following measurements were taken: body mass and stature, body mass index, skinfolds and circumferences were measured at standardized sites for calculation of body fat according to Jackson, Pollock and Ward, ventilatory threshold, heart rate and blood pressure. Changes in HR and BP and their variabilities were assessed from HR and BP recordings collected during seven consecutive days with the TM2421 ambulatory HR-BP monitors (A & D Company, Tokyo, Japan).

This study permits several conclusions regarding the effectiveness of walking as a means of cardio-respiratory conditioning for postmenopausal women. The overall conclusion is that 15 weeks of walking are sufficient for an increase in aerobic capacity, and that the magnitude of the effect will be, in agreement with Karvonen's observations, proportional to training intensity.

The second conclusion is that, under the conditions of this study, training intensity has pleiotropic effects on

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individual cardiorespiratory variables and their components. It significantly stimulated increases in aerobic capacity, but exerted insignificant lowering tendency on HR and BP parameters. Within each cardio-respiratory variable, only some components showed the effects of training intensity, while the others were unaffected. Thus, training intensity tended to decrease BPsys, BPdia, and HR MESORs, and usually only one measure of their variability (BPsys double amplitude, and BPdia and HR SDs).

*Key words:* adults, training intensity, health

## INTRODUCTION

As we age, our capacity for sustained and intense physical exertion declines. This partly represents a decline in cardio-respiratory capacity epitomized by relationship of the variables in the Fick equation: a lowering of the rate of oxygen consumption as a function of reduction in its two components, the cardiac output and tissue extraction of oxygen. The undesirable consequences of these changes include reduced capacity for heart rate acceleration (tachycardia) during exertion and increased risk of developing cardiovascular disease (CVD). CVD is the leading cause of death of older people in developed societies. Despite considerable interest in prevention and treatment of the decline in cardio-respiratory function, it is still not certain to what extent it is caused by irreversible features of aging and hence likely more resistant to intervention, and to what extent it is caused by a lifestyle of inactivity and excessive consumption of energy-rich food, in which case it should be more readily modifiable. Inactivity and excessive intake of energy-rich food are considered to be the chief causes of a metabolic syndrome characterized by some combination of hypertension, abdominal obesity, hyper-lipidemia, insulin resistance, and hyper-coagulability of blood. These in turn are risk factors for CVD and stroke (Kaplan, 1989, Opara and Levine, 1997). A decline in cardio-respiratory capacity with age is therefore of considerable interest as it interferes with a full range of physical activities in advanced years. It also is of considerable medical interest as it increases morbidity and importantly contributes to premature mortality.

Of the cardiovascular dependent variables in the Fick equation, ventilatory threshold (VT) as a measure of aerobic capacity (or oxygen consumption), and the heart rate (HR) component of cardiac output, are easy to measure. VT is a sensitive systemic index of the capacity for aerobic metabolism (Davis et al., 1976). As exercise intensity exceeds this capacity, increased production of lactic acid through anaerobic glycolysis triggers compensatory hyperventilation. Changes in aerobic capacity can therefore be monitored through measurements of VT. HR measurements are also indicative of individual's cardio-respiratory fitness both at rest (when the relationship is inverse) and during progressive physical challenge. In the latter case, the rate of HR acceleration to oxygen demands during progressive increase in exercise intensity is a measure of cardiac fitness. In addition, physical deconditioning is associated with decreased HR variability and may reflect excessive sympathetic and inadequate parasympathetic control of heart function (Malliani, 1999). Decreased HR variability also is associated with increased risk of death (Adamopoulos et al., 1999).

Blood pressure (BP) is a variable of cardio-respiratory function that participates in oxygen delivery during exercise and also has a profound impact on cardiovascular health. Systolic blood pressure (BPsys) increases during exercise, while vasodilatation in the large contracting muscle mass prevents a change, or causes a decrease, in diastolic pressure (BPdia). Age-associated increases in BP can damage circulation to kidneys and other vital peripheral organs, cause cardiac hypertrophy, and increase risk of stroke. While exercise training can reduce resting BPsys and BPdia, its effectiveness has not been universal, and at high training intensities, deleterious effects on BP have sometimes been observed. This lack of consensus regarding the effects of exercise on BP is reflected in the American College of Sports Medicine position stand (1998) that advocates moderate exercise training intensities for BP reduction. In contrast to HR variability, BP variability is positively correlated with increased risk of coronary heart disease and stroke (Kikuya et al., 2000). In addition to general BP variability, a circadian form of BP variability (Circadian-Hyper-Amplitude-Tension or CHAT) that consists of excessive diurnal elevations, and excessive nocturnal declines in BP, also confers an independent and significantly increased risk of stroke and nephropathy (Otsuka et al.,1996, 1997). The relation between the circadian amplitude and this risk appears to be non-linear (Cornelissen et al., 2000, 2001).

The aim of this study was to examine the extent to which a simple prototypic form of physical activity, walking, can improve components of cardio-respiratory function in aging individuals. Postmenopausal women were selected for study because of their demographic prevalence, general paucity of information on the effects of training on their cardio-respiratory function, and their increased risk of CHD following estradiol decline. Walking was selected because it is the principal physical means of human locomotion and dynamically engages large muscle groups. It also is universally accessible without the necessity for specialized equipment or facilities. Exercise intensity was selected as a focus of these studies as it holds both scientific and medical interest. Exercise intensity is the key element for effective cardio-respiratory training as identified by Karvonen almost half a century ago (Karvonen et al., 1957). On the other hand, intense exercise may cause excessive BP elevation and can infrequently cause cardiac death or stroke (Ciampricotti et al., 1989, 1990, Mittleman et al., 1993). If exercise is to be prescribed for cardio-respiratory health benefits, an understanding of the dose-response relationship between its intensity and the several components of cardio-respiratory function is a necessity.

## MATERIALS AND METHODS

*Subjects* were 42 generally healthy overweight to moderately obese postmenopausal women whose characteristics are shown in Table 1. They all agreed to participate in 15 weeks of training and signed an informed consent form approved by the University of Michigan School of Medicine Institutional Review Board.

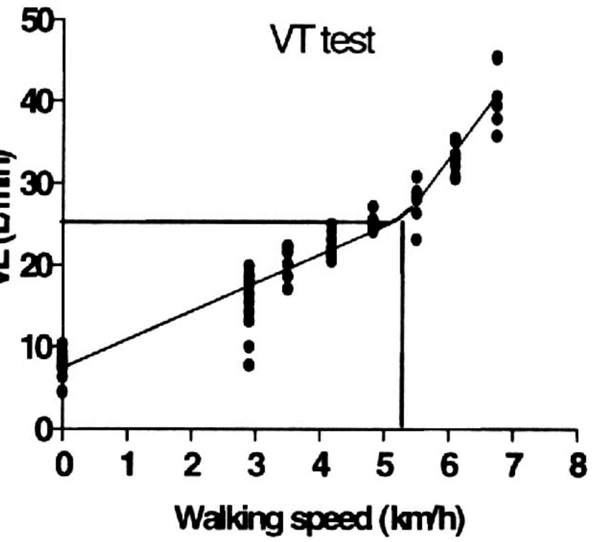
Table 1 Anthropometric characteristics of the 42 subjects before and after 15 weeks of training
Tablica 1. Antropometrijske karakteristike 42 ispitanika prije i poslije 15 tjedana treninga

| Variable | Before training | After training | p |
|---|---|---|---|
| Age (years) | 58 +/- 0.76* | | |
| Body mass (kg) | 77.5 +/- 1.7 | 76.9 +/- 2.0 | 0.09 |
| Stature (m) | 1.64 +/- 0.01 | | |
| BMI ($kg/m^2$) | 28.7 +/- 0.58 | 28.5 +/- 0.72 | 0.09 |
| Body fat (%) | 38.69 +/- 0.77 | 37.62 +/- 0.93 | 0.0012 |

Mean +/- SEM.
P values derived from Student's paired t tests.

*Training* consisted of walking 4.83 km/day five days a week for 15 weeks at an assigned intensity. Walking was carried out at a commercial mall, between 6:30 and 7:30 h, under supervision that included measurement of times and distances covered. Women were stratified by age, weight, body composition, and initial aerobic fitness and assigned to one of two exercise intensities, 95% of VT or 125% of VT. Individual VTs were established during a walking test on a level treadmill, during which ventilatory rate was measured, as walking speeds increased by 0.64 km/min every 3 minutes. VT was expressed as the exercise intensity at which there was a distinct increase in the rate of minute ventilation (Figure 1).

Figure 1 Ventilatory threshold (VT) test.
Slika 1. Ventilacijski prag




*Dependent variables*. Before the start, and after 15 weeks of training, the following measurements were taken. Body mass and stature were measured and used for calculation of body mass index (BMI, $kg/m^2$). Skinfolds and circumferences were measured at standardized sites for calculation of body fat (Jackson et al., 1980). VT was determined both for assignment to training intensity and as an indicator of aerobic capacity. HR was measured with a Polar tachometer during the treadmill walking test to determine the slope of tachycardia. Changes in HR and BP and their variabilities were assessed from HR and BP recordings collected during seven consecutive days with the TM2421 ambulatory HR-BP monitors (A & D Company, Tokyo, Japan). During HR and BP measurements, both before and after training, subjects did not engage in any organized physical activity.

*Statistical analyses*. The circadian patterns of HR and BP changes, including the mean estimate statistic of rhythm (MESOR), the magnitude of circadian swings above and below the MESOR (double amplitudes), and the standard deviations of HRs and BPs were calculated after fitting the HR and BP data to 24-h and 12-h cosine curves (Halberg, 1969). Student's t test for matched goups was used to assess changes in body mass, BMI, and body fatness as a result of training. Although the subjects were assigned to two distinct training speeds, their imperfect compliance resulted in two overlapping distribution curves of relative training intensities. A change in all cardio-respiratory dependent variables, between values obtained after 15 weeks of training and initial pre-training values, were subjected to regression analysis against relative training intensities. Probability of $< 0.05$ was used as the criterion of significant difference. A power test was used to estimate numbers of subjects needed for inclusion in future studies to have an 80% chance of achieving statistical significance at a probability level of 5% (Cohen, 1992).

## RESULTS AND DISCUSSION

*Anthropometric effects of training*. Training had no effect on the body mass or the BMI, but resulted in a significant loss of body fat ( t=3.591, df=29, Table 1). The modest 2-3% reduction in body fat is in agreement with the limited effectiveness of aerobic training in producing body fat loss observed by others. Modest body fat loss unaccompanied by a change in body mass agrees with the findings of others that exercise protects against losses of, or produces increases in, lean body mass at the same time as it facilitates some body fat loss (Ballor and Poehlman, 1994).

*Training intensity and changes in aerobic fitness*. Training intensity had a very significant stimulatory effect on aerobic capacity assessed from increases in VT (Table 2 and Figure 2). The relationship between the two variables ( y=0.4546x 41.02) indicates that training produced a 4.5% increase in the VT for each 10 percent increase in training intensity. The power test prediction of a significant positive relationship between walking intensity and increases in VT at the power of 80% called for as few as 13 subjects.

Table 2: Correlations between the intensity of training during 15 weeks of walking and changes in selected cardiovascular functions in postmenopausal women
Tablica 2.

| Variable | Measure | Coefficient of correlation (r) | p | Number of subjects needed for significance |
|---|---|---|---|---|
| VT (km/h) | | 0.658 | <0.001 | 13 |
| Systolic blood pressure (mm Hg) | MESOR | -0.175 | 0.425 | 202 |
| | Double-amplitude | -0.296 | 0.143 | 70 |
| | SD | -0.004 | 0.849 | 4185 |
| Diastolic blood pressure (mmHg) | MESOR | -0.269 | 0.184 | 89 |
| | Double-amplitude | -0.032 | 0.875 | 6097 |
| | SD | 0.200 | 0.316 | 153 |
| Heart rate (bpm) | MESOR | -0.332 | 0.122 | 55 |
| | Double-amplitude | 0.036 | 0.857 | 4689 |
| | SD | -0.103 | 0.267 | 582 |
| Exercise-induced tachycardia (slope) | | 0.124 | 0.501 | 4512 |

Figure 2 Change in ventilatory threshold as a function of training intensity
Slika 2. Promjena ventilacijskog praga kao funkcija intenziteta treninga

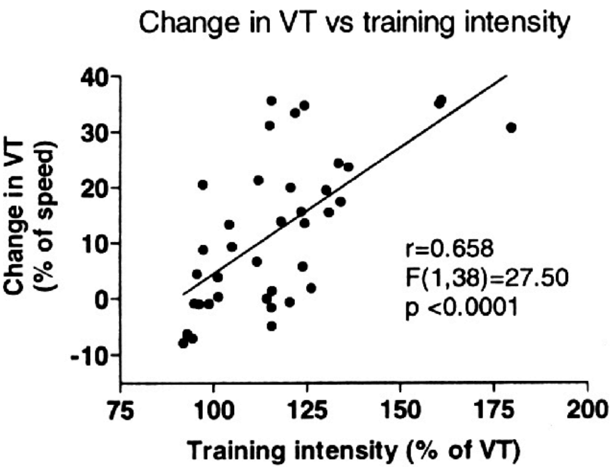
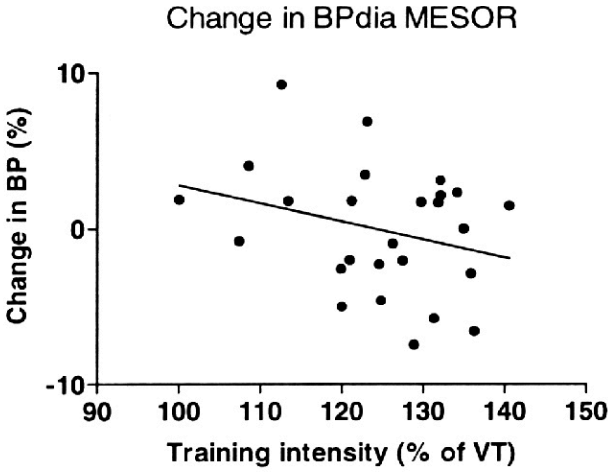



Figure 3 Change in BPdia MESOR as a function of training intensity.
Slika 3. Promjena Bpdia MESOR kao funkcija intenziteta treninga

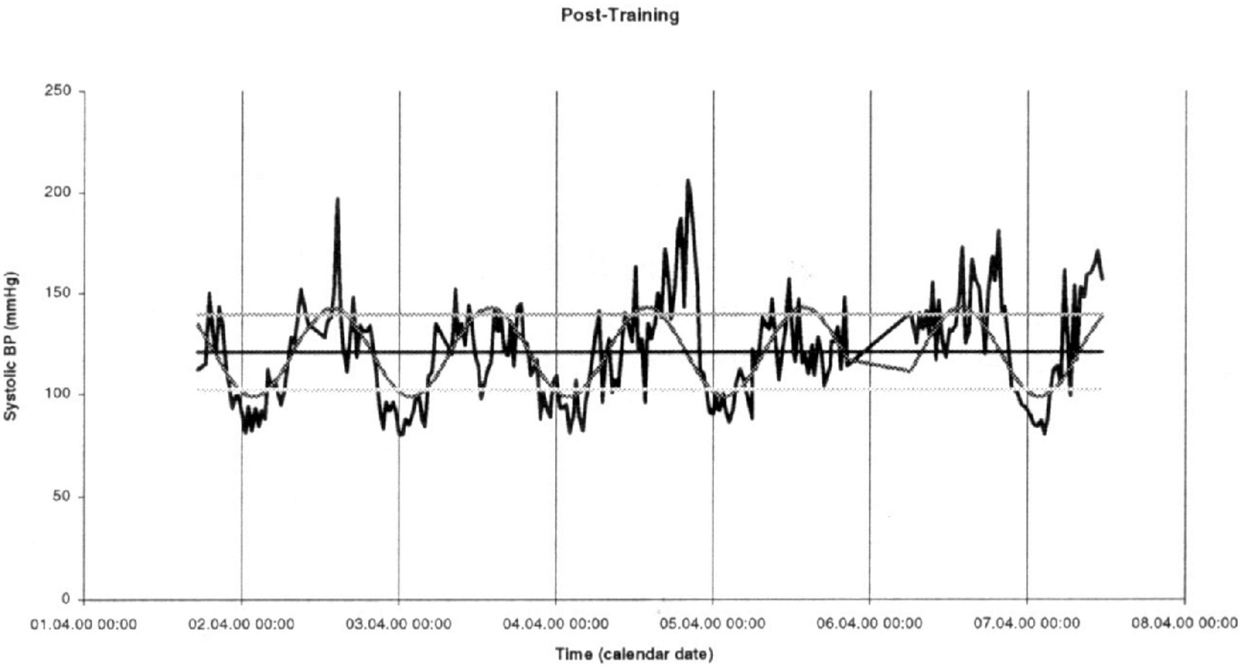



*Training intensity and changes in BP parameters*. In contrast to the highly significant effects of training intensity on VT as a measure of capacity to utilize oxygen, training intensity had a less pronounced effect on several measures of BP function (Table 2). In decreasing order of magnitude, training intensity tended to decrease circadian variability (double amplitude) of BPsys (Table 2), BPdia MESOR (Figure 3), the SD measure of BPdia variability, and BPsys MESOR (Table 2). In all four instances, the effect was proportional to exercise intensity. In no case did the effect reach significance. The power test prediction for the number of subjects required to attain significance was, respectively, 70, 89, 153, and 202 (Table 2). Thus, training intensity in the ranges attainable during 15 weeks of walking had a numerical, albeit not statistically significant, dose-dependent lowering effect on the four variables. However, judging from the power test predictions, this effect was, respectively, about 5, 7, 12, and 15 times smaller than the effect of training intensity on aerobic capacity. Training intensity had no measurable effect on the SD of BPsys variability or on the double amplitude of the BPdia variability (Table 2).

*Training intensity and changes in HR parameters.* Training intensity tended to decrease HR MESOR (Table 2). Although training intensity had no significant effect on any parameter of HR function, its effect on HR MESOR was second largest (albeit four times lesser) in magnitude after the effect of training intensity on changes in VT. There was a slight trend toward a decrease in the SD of HR variability with increases in training intensity. Power test prediction, however, was for 600 subjects for this effect to reach statistical significance. Unlike the beneficial trends in BP changes, training intensity tended to influence the SD of HR variability in the direction associated with increased risk of cardiac death. Training intensity had no effect on the double-amplitude measure of HR variability or slope of HR acceleration during the incremental treadmill walking test (Table 2).

*Training and circadian BP overswinging (Circadian-Hyper-Amplitude-Tension or CHAT)*. One of the 42 subjects studied exhibited acceptable MESOR BP values, but Figure 4 (data from Borer et al., 2002) indicates presence of CHAT with double amplitudes of BPsys in excess of the 90% prediction limits (upper and lower horizontal lines) for her age and gender. Her BPsys MESOR (middle horizontal line) was within the acceptable range before training, and 3 mmHg lower after training. In this subject, exercise training at 118.5% of her VT, also produced reductions in BPdia and HR MESORs, but had no effect on excessive circadian BPsys and BPdia double amplitudes.

Figure 4 Persistence of circadian hypertension or CHAT after 15 weeks of training.
Slika 4. Postojanost ritma hipertenzije ili CHAT poslije 15 tjedana treninga




## CONCLUSION

This study permits several conclusions regarding the effectiveness of walking as a means of cardio-respiratory conditioning for postmenopausal women. The overall conclusion is that 15 weeks of walking are sufficient for an increase in aerobic capacity, and that the magnitude of the effect will be, in agreement with Karvonen's observations (Karvonen et al., 1957), proportional to training intensity.

The second conclusion is that, under the conditions of this study, training intensity has pleiotropic effects on individual cardiorespiratory variables and their components. It significantly stimulated increases in aerobic capacity, but exerted insignificant lowering tendency on HR and BP parameters. Within each cardio-respiratory variable, only some components showed the effects of training intensity, while the others were unaffected. Thus, training intensity tended to decrease BPsys, BPdia, and HR MESORs, and usually only one measure of their variability (BPsys double amplitude, and BPdia and HR SDs). Although this study had insufficient power to definitively establish these relationships, it is reasonable to infer that, within the moderate range attainable by walking, training intensity could have a beneficial modifying effect on MESORS and mean values of BPsys, BPdia, and HR. These conclusions are in agreement with training studies performed at an intermediate range of intensities by others (Fagard, 2001, Kelley and Kelley, 1999, Kelley & Sharp Kelley, 2001).

In contrast to apparent modifiability by exercise training of BP and HR MESORs, the rate of HR acceleration during progressive treadmill walking test, and some measures of HR and BP variability were unaffected by training intensity. The first variable reflects the well-known age-associated decline in maximal heart rate (Tanaka et al., 2001) and is most likely related to change in contractile characteristics of heart muscle fibers (Long et al., 1999) as well as age-associated reduction in their responsiveness to sympathetic stimulation (Esler et al., 1995, Seals et al.,1994). In some studies, higher levels of aerobic fitness are associated with greater HR variability (Davy et al., 1996,1998, Gregoire et al., 1996) . This would predict a positive influence of aerobic training on this variable in contrast to the trend toward reduced HR variability observed in the present study. The selective effect of training intensity on some parameters of BP (BPsys double amplitude, BPdia SD) and HR variability (HR SD), but not the others, requires further study and suggests that training intensity may affect the individual variables differently.

Finally, it is useful to acknowledge that BP is under multifactorial control. This is apparent when BP abnormalities are considered without and within the circadian context. Circadian and casual BP values may independently conform or diverge from their respective norms, as exemplified by the individual described by Borer at al. (2002) who was MESOR normortensive but exhibited excessive circadian double-amplitude swings.

Her CHAT conferred an independent increased risk of stroke in spite of her normal average blood pressure. Training lowered her already acceptable BPsys, BPdia, and HR MESORs, but had no effect on, or slightly exacerbated, her CHAT. This suggests that different mechanisms coordinate BP and HR MESORs on one hand, and their circadian swings on the other. Much more research is needed for a better understanding of the effect of exercise training on these cardio-respiratory variables. The use of ambulatory HR-BP monitors over several days, allows assessment of MESORs as well as circadian changes (Halberg et al., 2002) and thus represents a particularly useful approach to study these variables in response to exercise training.

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