Comparison of morning versus evening aerobic-exercise training on heart rate recovery in treated hypertensive men: a randomized controlled trial

Leandro C. Brito[a], Tiago Peçanha[a], Rafael Y. Fecchio[a],
Andrea Pio-Abreu[b], Giovânio Silva[b], Décio Mion-Junior[b],
John R. Halliwill[c] and Cláudia L. M. Forjaz[a]

Heart rate recovery (HRR) is a marker of cardiac autonomic regulation and an independent predictor of mortality. Aerobic-exercise training conducted in the evening (evening training) produces greater improvement in resting cardiac autonomic control in hypertensives than morning training, suggesting it may also result in a faster autonomic restoration postexercise. This study compared the effects of morning training and evening training on HRR in treated hypertensive men. Forty-nine treated hypertensive men were randomly allocated into three groups: morning training, evening training and control. Training was conducted three times/week for 10 weeks. Training groups cycled (45 min, moderate intensity) while control group stretched (30 min). In the initial and final assessments of the study, HRR60s and HRR300s were evaluated during the active recovery (30 W) from cardiopulmonary exercise tests (*CPET*) conducted in the morning and evening. Between–within ANOVAs were applied ($P \leq 0.05$). Only evening training increased HRR60s and HRR300 differently from control after morning *CPET* (+4 ± 5 and +7 ± 8 bpm, respectively, $P < 0.05$) and only evening training increased HRR300s differently from morning training and control after evening *CPET* (+8 ± 6 bpm, $P < 0.05$). Evening training improves HRR in treated hypertensive men, suggesting that this time of day is better for eliciting cardiac autonomic improvements via aerobic training in hypertensives. *Blood Press Monit* XXX: 000–000 Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.

Introduction

Autonomic dysfunction is one of the main pathophysiological mechanisms involved in hypertension. Heart rate recovery (HRR) after maximal exercise testing is a low-cost, noninvasive and useful tool to assess cardiac autonomic function [1]. It has also been shown to be an independent predictor of all causes and cardiovascular mortalities [2,3].

Aerobic-exercise training is recommended for the treatment of hypertension. In addition to decrease blood pressure, aerobic training improves resting cardiovascular autonomic modulation in hypertensives and accelerates HRR after exercise [4]. However, the effects of aerobic training on autonomic control may vary depending on the time of day in which training sessions are performed. Along these lines, recent studies have reported different HRR and sympathovagal balance after a single session of aerobic exercise performed in the morning versus in the evening [5,6].

Furthermore, the chronic effects of aerobic training have been shown to vary depending on the time of day of the training, with late afternoon training promoting greater improvement in HRR than morning training in healthy subjects [7]. In hypertensives, we have demonstrated greater blood pressure reductions and improvement in resting cardiac baroreflex sensitivity after evening than morning training [8]. Hence, training at this time of day may also produce greater improvements in cardiac autonomic regulation after exercise, resulting in a greater HRR. To the best of our knowledge, this has not been investigated in this population.

Therefore, the present study tested this hypothesis, comparing the effects of morning versus evening aerobic-exercise training on HRR during the active recovery from a maximal exercise test in treated hypertensive men.

Methods

The study used secondary data from a randomized controlled trial approved by the Research Ethical Committee

of the School of Physical Education and Sport of the University of São Paulo (nº 966.072) and registered at the Brazilian Clinical Trials (www.ensaiosclinicos.gov.br - RBR-7q7pz7). The main results of the original trial have been published elsewhere [8].

Study design and experimental protocol

The current study is a randomized controlled trial in which hypertensive men receiving consistent antihypertensive treatment for at least 4 months and attending to all study criteria (Appendix 1, Supplemental digital content 1, *http://links.lww.com/BPMJ/A139*) underwent two maximal cycle ergometer cardiopulmonary exercise tests (CPET) conducted with a ramp protocol of 15 W increment every minute, preceded by a 3-min warm-up at 30 W and followed by 5 min of active recovery at 30 W (detailed in Appendix 2, Supplemental digital content 1, *http://links.lww.com/BPMJ/A139*). The tests were conducted in a random order (simple raffle) with an interval of at least 72 h between them. One test was conducted in the morning (7–9 a.m.) and the other in the evening (8–10 p.m.). After this initial evaluation, the subjects were randomly allocated as previously described [8] in one of three groups: morning training (morning training, 7–9 a.m); evening training (evening training, 6–8 p.m.); and control (control: stretching training – half of the subjects in the morning and a half in the evening). Interventions were conducted three times per week for 10 weeks with aerobic training performed on a cycle ergometer (CEFISE, Biotec 2100, Campinas, Brazil) at moderate intensity and lasting from 30 to 45 min (detailed

Table 1   Physical and clinical characteristics of the morning training, evening training and control groups assessed at the beginning of the study

Variables	Morning training	Evening training	Control
N	15	15	19
Age (years)	51 ± 8	49 ± 8	50 ± 10
Height (m)	1.72 ± 0.06	1.70 ± 0.10	1.71 ± 0.07
Weight (kg)	87.4 ± 12.1	89.5 ± 14.9	87.3 ± 15.8
BMI (kg/m^2)	29.6 ± 3.1	30.7 ± 3.3	29.6 ± 4.3
Chronotype (score)	52 ± 6	56 ± 3	53 ± 4
Hemodynamics			
Resting systolic blood pressure (mmHg)	135 ± 9	132 ± 6	134 ± 13
Resting diastolic blood pressure (mmHg)	92 ± 7	89 ± 5	89 ± 8
Heart rate (bpm)	74 ± 9	77 ± 10	76 ± 11
Type of antihypertensive therapy			
One – no. (%)	11 (73)	10 (67)	14 (74)
Two or more – no. (%)	4 (27)	5 (33)	5 (26)
Antihypertensive drugs			
Angiotensin II receptor blockers – no. (%)	8 (53)	7 (47)	9 (47)
Angiotensin-converting enzyme inhibitors – no. (%)	6 (40)	7 (47)	7 (37)
Dihydropyridine calcium channel blockers – no. (%)	4 (27)	3 (20)	4 (21)
Diuretics – no. (%)	4 (27)	5 (33)	4 (21)

Data: mean ± SD. Comparison with one-way ANOVA or chi-square test. No significant differences.

at Appendix 3, Supplemental digital content 1, *http://links.lww.com/BPMJ/A139*). At least 48 h after the last intervention session, a final evaluation was conducted in which morning and evening CPETs were repeated in the same order as in the initial evaluation.

Outcomes

During CPET and active recovery, heart rate (HR) was continuously assessed by an HR monitor (POLAR 800cx, Kempele, Finland). After data transmission to the Polar Pro Trainer Software, HR signal underwent a moving average filter before analyses (v. 5.0, Polar Inc., Kempele, Finland). Peak HR was considered as the highest value achieved at the end of the exercise phase of the test. HRR was analyzed by HRR60s and HRR300s calculated by the absolute differences between peak HR and HR obtained at 60 s and 300 s of recovery, respectively. The first index represents cardiac parasympathetic reactivation, while the second index represents cardiac parasympathetic reactivation plus sympathetic withdraw [1,9].

Statistical analysis

As this study used secondary data from another trial [8], a priori sample size was not calculated for HRR. Nevertheless, posteriori power analyses revealed β ≥ 0.80 for all variables, showing an adequate statistical power for all of the study outcomes.

Comparisons among the interventions were applied separately for CPETs conducted in the morning and the evening using two-way mixed ANOVAs that considered group (morning training, evening training and control) as the between main factor and time (initial vs. final) as the within main factor. Newman−Keuls tests were applied as post hoc when necessary. Analyses used a specific statistical software package (Statsoft v.5, Statistic for windows, USA). Data are shown as mean ± SD, and $P \leq 0.05$ was considered significant.

Results

The study flowchart is presented in accordance with the CONSORT in Appendix 4, Supplemental digital content 1, *http://links.lww.com/BPMJ/A139*. After randomization, three subjects from each training groups dropped out for personal reasons (i.e. total of six). Forty-nine subjects (morning training = 15, evening training = 15 and control = 19) underwent all the study phases and composed the final sample. Physical and clinical characteristics were similar among the groups at the beginning of the study (Table 1). Adherence to interventions, workload and HR achieved during the aerobic training as well as improvements obtained in peak VO$_2$ and workload were similar between morning training and evening training as previously shown [8] and described in Appendix 5, supplement digital content 1, *http://links.lww.com/BPMJ/A139*.

CPETs conducted between 7 and 9 a.m.: Peak HR achieved during morning CPET did not change from

Fig. 1
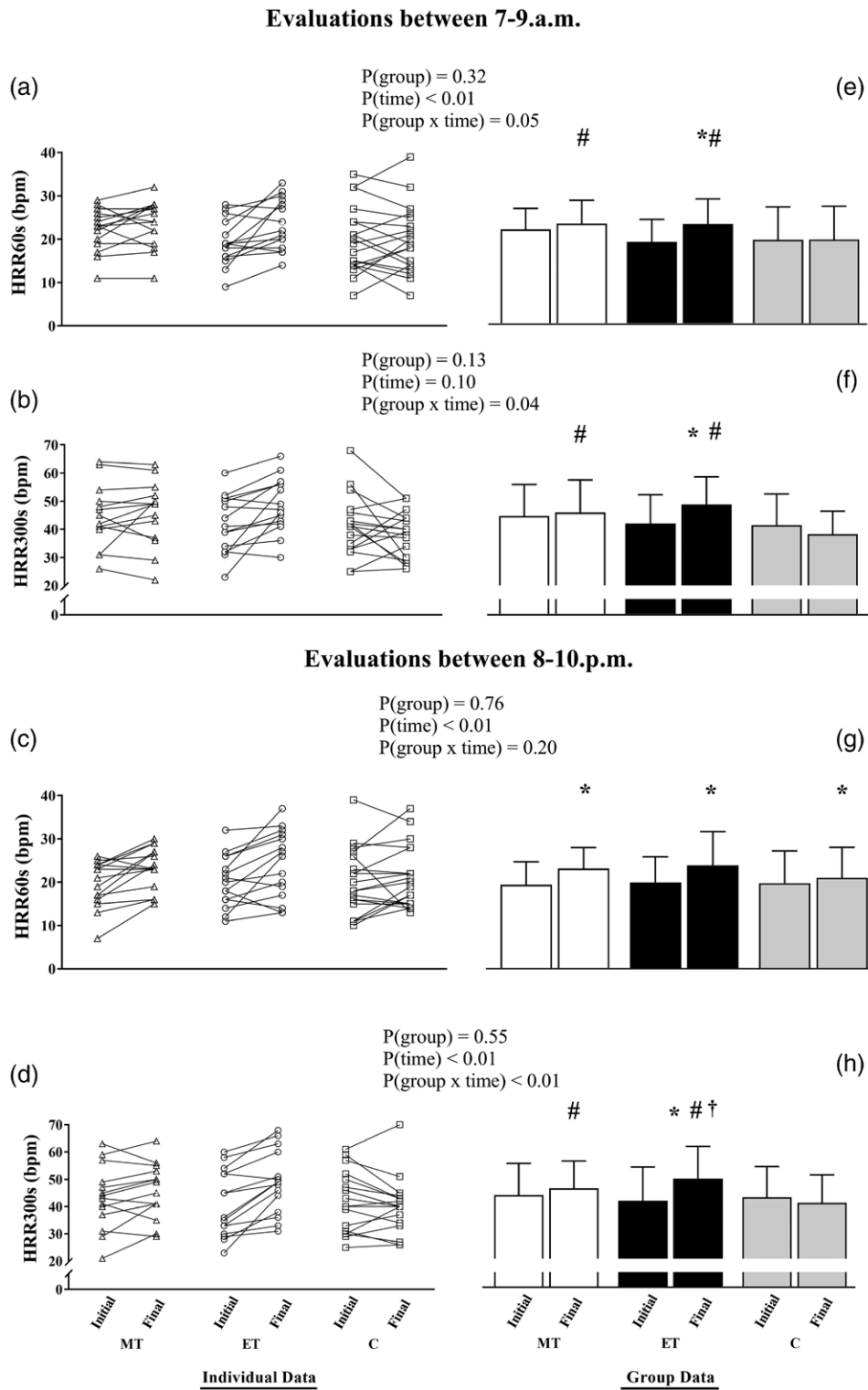
Heart rate recovery indexes measured in the morning (7–9 a.m. – Individual data: a, b; Group data: e, f) and evening (8–10 p.m. – Individual data: c, d; Group data: g, h) evaluations conducted at the initial and the final assessments of the study in three groups: Aerobic training in the morning (morning training, white bars; triangles), aerobic training in the evening (evening training, black bars; circles) and control (gray bars; squares). HRR60s – heart rate recovery at 60 s of recovery; HRR300s – heart rate recovery at 300 s of recovery. *Significantly different from the initial evaluation in the same group ($P \leq 0.05$). #Significantly different from the control group at the same evaluation ($P \leq 0.05$). †Significantly different from the morning training group at the same evaluation ($P \leq 0.05$).

the initial to the final evaluation in either group (morning training: 156 ± 14 vs. 153 ± 20; evening training: 163 ± 15 vs. 164 ± 14; and control: 157 ± 16 vs. 151 ± 18 bpm, $P = 0.17$). HRR60s and HRR300s increased significantly from the initial to the final evaluation only in evening training, and these indexes measured at the final evaluation were significantly higher in both morning training and evening training than in control (Fig. 1e,f).

CPETs conducted between 8 and 10 p.m.: Peak HR achieved in evening CPET did not change from the initial to the final evaluation in either group (morning training: 160 ± 17 vs. 157 ± 17; evening training: 163 ± 13 vs. 166 ± 12; and control: 158 ± 15 vs. 153 ± 15 bpm, $P = 0.08$). HRR60s increased significantly and similarly from the initial to the final evaluation in all groups ($P < 0.01$ for time factor), while HRR300s increased significantly only in evening training, and HRR300s in the final evaluation was significantly greater in evening training than morning training and control (Fig. 1g,h).

Discussion

The main finding of this study was that only aerobic-exercise training conducted in the evening improved HRR as observed after CPET in treated hypertensive men, indicating, as hypothesized, that training at this time of day produces greater improvements in cardiac autonomic restoration after exercise.

Evening training consistently increased the fast (HRR60s) and the slow (HRR300s) phases of HRR, indicating that training at this time of day improved both branches of the cardiac autonomic system (parasympathetic and sympathetic) [1,9]. Additionally, this benefit after evening training was observed in CPETs conducted at both times of day (7–9 a.m. and 8–10 p.m), showing that the effect is not limited to the time when subjects have exercised. It is also interesting to note that HRR indexes were greater in morning training than control at the final evaluation, although there was no significant change from the initial to the final evaluation in morning training. Such results suggest a slight but not significant effect of training conducted in the morning on HRR, which is consistent with a previous study [10]. It is possible that morning training needs a longer period of training or higher intensity to promote significant autonomic adaptations. This could be a focus of future studies.

The improvement in HRR observed after evening training may have a clinical impact. Although this study did not include a healthy group for comparison, the mean HRR300s assessed in the initial evaluation in the three groups were lower than 55 bpm (i.e. the cutoff point for increased risk for mortality), indicating an impaired cardiovascular autonomic control [2]. After evening training, HRR300s increased in all but one subject, with mean values increasing by $+7 \pm 8$ and $+8 \pm 6$ bpm for CEPTs

conducted at 7–9 a.m. and 8–10 p.m, respectively. This result demonstrates a faster restoration of cardiac autonomic control induced by training at this time. These increases may represent an important clinical improvement since a 10 bpm decrease in this variable is associated with an increase of 1.1 of the hazard ratio of death [3]. Noteworthy, in addition to the benefits revealed in the present study, our previously published data showed greater effects of evening training than morning training in reducing clinic and ambulatory blood pressure and improving cardiac baroreflex sensitivity [8]. These observations strengthen the possibility that there is a clinical impact of training at this time of day in these patients.

The current study's results are limited to treated hypertensive men who were middle-aged, not physically trained and not extreme chronotypes. Although an important aspect of this research is the clear benefit of aerobic-exercise training in the evening for hypertensive men, it will be important to extend these results by performing studies in hypertensive women, trained subjects and older patients. It would also be interesting to know if individuals with extreme chronotypes show a similar response to training at different times of the day.

In conclusion, aerobic-exercise training conducted in the evening improves HRR in treated hypertensive men, suggesting that training at this time of day is better for inducing cardiac autonomic adaptations in hypertension.

Acknowledgements

Conflicts of interest
There are no conflicts of interest.

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