Effects of Treadmill Running and Resistance Exercises on Lowering Blood Pressure During the Daily Work of Hypertensive Subjects

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Abstract

Mota, MR, Pardono, E, Lima, LCJ, Arsa, G, Bottaro, M, Campbell, CSG, and Simões, HG. Effects of treadmill running and resistance exercises on lowering blood pressure during the daily work of hypertensive subjects. J Strength Cond Res 23(8): 2331–2338, 2009—The purposes of this study were to compare the hypotensive effects of treadmill running (TR) and resistance exercise (RE) performed by hypertensive subjects and to verify if the hypotensive effects of these exercises are maintained during a regular white-collar workday. Fifteen white-collar workers (42.9 ± 1.6 years), treated with antihypertensive medication, accomplished three different sessions: 20 minutes of TR (~70–80% of heart rate reserve), 20 minutes of circuit training RE (20 repetitions at 40% of 1 repetition maximum), and a control session without exercise (CON). The systolic blood pressure (BP), diastolic BP, heart rate, and blood lactate were measured at resting (Rest) and after sessions at 15th (R15), 30th (R30), 45th (R45), and 60th (R60) min, as well as after lunch (AL), four (R4h) and seven (R7h) hours of recovery at the participants’ workplace. In relation to rest, a higher decrease of systolic BP after TR (~11.1 ± 7.6 mm Hg) and RE (~12.6 ± 7.3 mm Hg) was observed respectively at the R30 and R45. For diastolic BP, the highest decreases after TR (~4.0 ± 6.4 mm Hg) and RE (~9.0 ± 7.0 mm Hg) were observed respectively at the R45 and R30. The systolic BP and mean BP after TR and RE differed significantly from CON session (p < 0.05), and lower post-exercise values could be observed over the workday. In conclusion, both 20 minutes of TR and RE resulted in postexercise hypotension, and were able to reduce BP throughout 7 hours after exercise, even throughout the subject’s regular occupational activities. Also, the RE promoted higher cardiac protection and can be a useful model of physical exercise prescription for hypertension individuals.

Key Words exercise, postexercise hypotension, aerobic training, circuit resistance training

Introduction

The prevalence of hypertension in some regions of Brazil reaches 40% of the population (40). There are many options for treating hypertension and preventing risk factors associated with cardiovascular diseases (30), including physical exercise. Both acute and chronic exercise have been recommended as a non-pharmacological and less expensive treatment of hypertension (26,36). An important effect of acute exercise that may be useful for blood pressure control is a phenomenon called postexercise hypotension (PEH).

PEH is defined as a reduction in systolic and/or diastolic blood pressure after a single bout of exercise to values below those observed during pre-exercise resting. The PEH has been observed in both hypertensive and normotensive, young, and elderly individuals (13,16,22). The mechanisms responsible for PEH remain unclear and may be related to a reduction in cardiac output (33) and/or in peripheral vascular resistance (17). The PEH may be associated to a shift in the baroreflex control and a reduction in the alpha-adrenergic responsiveness, as well as to an increased secretion of humoral, hormonal, and local substances associated to vasodilatation in response to exercise (20,28).

Studies have showed that PEH may last for as long as 2 hours in healthy individuals (23,24,33), with evidence of the effect of exercise on lowering blood pressure lasting several hours in hypertensive individuals (34). The magnitude and duration of PEH depends on the studied population (normotensive or hypertensive) (34), the exercise modality and intensity (15,33), and the exercise duration (23).

Recent investigations have demonstrated that PEH occurs in response to continuous dynamic exercise (i.e., running and cycling) (18,21,37), and intermittent exercise sessions...
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(i.e., resistance exercises) (10,14,25,38). MacDonald et al. (21) found an attenuated response of blood pressure during daily living activities performed by hypertensive subjects during the postexercise period when subjects presented PEH (after 30 min of cycling at 70% of $V_o_2peak$). However, it remains unclear if the PEH would be sustained for prolonged periods of time under real daily life activities and working conditions. The effects of exercise modality on these responses are also unclear. Likewise, we are unaware of any published studies comparing the effects of treadmill running and resistance exercise sessions, performed with similar duration, on the hemodynamic responses of hypertensive individuals during their daily work.

Considering the benefits of exercise in reducing blood pressure, it was hypothesized that even 20 minutes of treadmill running as well as 20 minutes of resistance circuit exercise are able to promote PEH, which can be sustained during daily working conditions. If confirmed, the results would support the prescription of resistance exercise for lowering blood pressure of hypertensive individuals even during their real daily life activities. Thus, the aims of the present study were a) to compare the hypotensive effects of treadmill running and resistance exercise performed by hypertensive subjects; and b) to verify if the hypotensive effects of these exercises would be maintained for these subjects during a regular white-collar workday.

Methods

Experimental Approach to the Problem

On different days, and at the same time of day (9:20 AM), the same volunteers were randomly submitted to two different exercise sessions and one control session as follows: a) 20 minutes of circuit training resistance exercise, b) 20 minutes of treadmill running, and c) 20 minutes of a control session without exercise. An interval of at least 72 hours between sessions was given to the participants. During these procedures the systolic, diastolic, and mean blood pressure were monitored before, during, and after exercise or control to analyze PEH. In addition, the blood lactate and double product were obtained to verify metabolic and cardiovascular stresses, respectively.

Before the first of these three sessions, a one repetition maximum test and a maximal treadmill graded exercise test were assessed on different days. The participants were asked to avoid alcohol, caffeine, and strenuous physical exercise at the day before the tests. All exercise sessions were performed at the workplace exercise room.

Subjects

The local Ethics Committee for Humans Research, which is associated with the National Ethics Committee in Researches (CONEP) from Brazil, approved the methods involved in this study which followed the directions stated by the American College of Sports Medicine (ACSM)’s policies with regards to human experimentation. The subjects were informed of all possible risks and stresses associated to the experimental procedures and signed a written informed consent prior to participation. Fifteen (13 men and 2 women) middle-aged (42.9 ± 1.6 years) white-collar workers and with history of hypertension (2–3 years) volunteered to participate in this investigation. During previous medical screening, and accordingly to ACSM’s position stand on blood pressure (5,32), the participants were classified as hypertensive (stage 1), which is associated to blood pressure values of 140–159 or 90–99 mm Hg for systolic or diastolic, respectively. The blood pressure of all 15 subjects was controlled pharmacologically during the entire study. Eight subjects were taking beta-blockers, and seven subjects were taking calcium antagonists associated with angiotensin converting enzyme inhibitors. Also, personal physicians cleared the subjects for inclusion in the study. The qualification criteria for the study included the absence of an acute or terminal illness, musculoskeletal disease, an unstable cardiovascular condition, including a recent history of heart failure, arrhythmias, myocardial infarction and stroke, ischemia or any other medical contraindication to perform exercise. The subjects’ work activities consisted mainly of administrative duties. The volunteers work shift was from 9:00 AM to 6:00 PM with a 1-hour lunch break. The characteristics of the volunteers are presented in Table 1. All subjects were considered physically active (~1.6 year of training; $V_o_2peak = 42.8 ± 2.6$ mL kg$^{-1}$·min$^{-1}$) by having consistently performed a minimum of two strength and/or aerobic workout sessions per week for the previous 1 year.

<table>
<thead>
<tr>
<th>Table 1. Participant characteristics ($n = 15$).*</th>
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<tr>
<td>Weight (kg)</td>
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<tr>
<td>Mean 81.4 42.9 172.7 26.8 19.6 134.0 84.9 77.7 42.8 194.5 91.9</td>
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<tr>
<td>SE 3.9 1.6 2.4 1.0 1.8 3.7 2.8 3.2 2.6 7.8 2.5</td>
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*BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate.
Procedures

Maximal Treadmill Graded Exercise Test. The maximal heart rate was determined by a treadmill graded exercise test until exhaustion. Participants received a verbal overview before the test. All tests were supervised by a medical doctor. An electrocardiogram recorded heart rate continuously. Both the maximal heart rate attained during the test and the pre-exercise resting heart rate were recorded and used to calculate the heart rate reserve (HRres) as follows: HRres = maximal heart rate – maximal heart rate (220 – age) – resting heart rate. In order to accurately prescribe and control the exercise intensity during the TR session, subjects were not asked to withdraw the blood pressure medication during this test.

One Repetition Maximum Test. The one repetition maximum (1RM) test was applied to all exercises used in the resistance exercise session to obtain the maximal load (kilograms) against which the individual could perform a correct (complete) movement (29).

Submaximal Resistance Exercise Session. A circuit model for resistance exercise (RE) composed by 13 resistance exercises was applied in this study. The exercises were performed in the following order: a) leg extension; b) hip adduction; c) hip abduction; d) bench press; e) leg press; f) pull-over; g) standing leg flexion; h) pull-up; i) hip adduction; j) biceps curl; k) leg press; l) trunk extension; and m) shoulder press. For each set of exercise, 20 repetitions at 40% of the 1RM test were performed. The circuit session lasted ~20 minutes. Each station/exercise was performed in ~60 seconds and the rest interval between exercises lasted 30 seconds.

Submaximal Treadmill Running Session. The treadmill running (TR) lasted 20 minutes and was performed with a 1% grade slope (PRO-Form ex 585–2.5HP, Smithfield, UT, USA). To attain a target of heart rate corresponding to ~70–80% of heart rate reserve, the treadmill velocity was adjusted within the first 5 minutes of exercise. Also, the treadmill velocity and the heart rate response were monitored continuously during the exercise.

Control Session. During the control session (CON), blood pressure and heart rate measurements were obtained at the same time points of the experimental exercise sessions (RE and TR) with the participant resting in a seated position.

Body Composition, Blood Cholesterol, and Blood Glucose. In order to characterize the sample, skinfolds measurements (Cambridge Scientific Industries, Inc., Cambridge, MA, USA) were used to assess body composition. Three-site skinfolds measurement equation was used for determining body density and then the relative body fat was calculated using the Siri’s formula. Fasting blood glucose was determined by using a blood glucose analyzer (model 2700 STAT, Yellow Springs Instruments, Yellow Springs, OH, USA). Blood cholesterol was determined using a commercially available kit (Sigma Diagnostics, St. Louis, MO, USA; Table 1).

Blood Pressure and Heart Rate. For each exercise (TR and RE) and CON sessions, resting systolic BP, diastolic BP, mean BP, and heart rate were obtained every 5 minutes during 20 minutes in a seated position and averaged to represent the resting (Rest) values. Postexercise BP and heart rate were assessed at the end of each exercise session (R0), and at 15 minutes (R15), 30 minutes (R30), 45 minutes (R45), and 60 minutes (R60) during the first hour of the postexercise recovery. The BP measurement, immediately after RE or TR (R0), was obtained through an auscultator method. These blood pressures and heart rate measurements were also performed after lunch (AL) between 12:30 and 1:00 PM (~2.5 hours of postexercise recovery), as well as 4 (R4h, 2:00 PM) and 7 (R7h, 5:00 PM) hours of recovery. The last measurements (AL, R4h, and R7h) were taken at the workplace in a quietly condition with the participant seated. During postexercise period, the heart rate (T71 Polar Sport Tester Monitor, Finland), systolic BP, and diastolic BP (Microlife BP 3AC1, Switzerland) were automatically measured. During the measurements an apparatus was used to support the arm in a standard height, perpendicular to the heart.

Blood Lactate and Double Product. With the purpose to determine the metabolic and cardiovascular stress of each session (TR, RE, CON), blood lactate concentration was measured and the double product (double product = heart rate × systolic BP) was calculated. For blood lactate measurements, a 25-μL blood sample was collected from the earlobe at rest, and at the same postexercise moments of the heart rate and BP measurements. Blood lactate concentration was eletroenzimatically determined (2700 STAT, Yellow Springs Instruments).

Statistical Analysis

Data are presented as mean values ± SE. PEH within each session (TR, RE, and CON) was analyzed by a repeated-measure one-way analysis of variance. Delta variation (postexercise BP – pre-exercise BP) data were analyzed using two-factor 3 × 9 repeated measures analysis of variance [session (TR, RE, and CON) × time (Rest, R0, R15, R30, R45, R60, AL, R4h, and R7h)] for all BP measurements, where the variable’s scores showed a normal distribution. A Pearson’s moment correlation was applied to analyze the relationship between blood lactate and postexercise BP, as well as between double product and postexercise BP. F ratios for main effects and interactions were considered significant at p < 0.05 in all comparisons. Main effect differences were interpreted using a Tukey’s post-hoc procedure.

Results

Despite being hypertensive, the participants were relatively fit (VO2peak of 42.8 ± 2.6 ml·kg⁻¹·min⁻¹), yet slightly overweight (body mass index 26.8 ± 1.0 kg·m⁻²). Mean 1RM loads were: leg extension, 51.9 kg; hip adduction, 60.7 kg; hip abduction, 62.0 kg; bench press, 47.7 kg; leg press, 123.8 kg;
pull-over, 22.5 kg; standing knee flexion, 4.8 kg; pull-up, 23.1 kg; biceps curl, 22.3 kg; trunk extension, 67.8 kg; and shoulder press, 21.5 kg.

The maximal heart rate attained during the graded exercise test was 176.3 ± 2.0 beats-min⁻¹. During the TR experimental protocol mean running velocity was 7.6 ± 0.2 km·h⁻¹, and mean running heart rate was 145.7 ± 1.9 beats·min⁻¹. The heart rate reached during the TR corresponded to 70.7 ± 2.0% of the rate heart reserve and to 80 ± 9.1% of the maximal heart rate obtained at the end of graded exercise test.

The BP responses during TR, RE, and CON are presented in Figure 1a–c. The BP values were compared within treatments (CON, TR, and RE) and significant differences were found for systolic BP ($F = 26.711–51.658$, $p < 0.0001$), diastolic BP ($F = 19.373–27.148$, $p < 0.0001$) and mean BP ($F = 19.640–43.900$, $p < 0.0001$). In addition, the results of delta variation (postexercise minus pre-exercise BP) of systolic, diastolic and mean BP were compared among sessions at each postexercise moment and significant differences were also verified ($F = 4.418–5.447$, $p < 0.0001$).

In relation to pre-exercise resting, a significant ($p < 0.05$) PEH of systolic BP was observed after both TR and RE. However, the PEH lasted longer after TR than RE (Figure 1a). A significant ($p < 0.05$) PEH of diastolic BP was observed only after RE at the 30th minute of recovery (Figure 1b) while the PEH of mean BP was similar for both TR and RE (Figure 1c).

In relation to pre-exercise resting, a higher decrease of systolic BP after TR ($−11.1 ± 7.6$ mm Hg) and RE ($−12.6 ± 7.3$ mm Hg) was observed respectively at the R30 and R45. For the delta of diastolic BP, the highest decreases after TR ($−4.0 ± 6.4$ mm Hg) and RE ($−9.0 ± 7.0$ mm Hg) were observed respectively at the R45 and R30. The systolic BP and mean BP delta variation after TR and RE differed significantly from CON session ($p < 0.05$) and could be observed over the workday (Figure 1a, b).

The blood lactate during the TR (5.0 ± 0.7 mmol·L⁻¹), RE (8.8 ± 0.6 mmol·L⁻¹), and CON (1.3 ± 0.1 mmol·L⁻¹) differed significantly from each other ($p < 0.05$), indicating a higher metabolic stress for the RE session. The double product reached on the TR (22,453 ± 552 mm Hg·min⁻¹), RE (15,443 ± 589 mm Hg·min⁻¹) and CON (8,693 ± 383.4 mm Hg·min⁻¹) also differed from each other ($p < 0.05$), suggesting a higher cardiovascular stress for the TR in relation to RE (Figure 2).
The Pearson’s moment correlation showed a moderate but significant correlation between blood lactate level at the end of RE (R0) and the delta of systolic BP decrease at the 30th minute ($r = 0.515$) and 45th minute ($r = 0.541$) of postexercise recovery. The blood lactate levels were also negatively correlated ($r = -0.535$) to the delta of mean BP decrease at the 45th minute of recovery. No significant correlation was observed between blood lactate at the end of TR and BP for any time of postexercise recovery from this session. Also, no significant correlation was found between double product at the end of both TR and RE to the systolic BP, diastolic BP, and mean BP delta variation.

**DISCUSSION**

The present study analyzed the effects of treadmill running and resistance exercise, both with 20-minute duration, on BP responses during 7 hours of postexercise recovery at a free-living workday in hypertensive subjects. The main findings were that a PEH was observed after both TR and RE, and lasted for at least 1 hour after RE and $\sim 2.5$ hours after TR. However, when compared to the control session, the results suggested that the exercise sessions evoked significant lower BP values than those of the CON session during at least 7 hours after the exercises, even during occupational activities (Figure 1a–c). Despite a similar PEH of systolic BP and mean BP, the PEH of diastolic BP was observed only at the 15th minute of recovery after the RE session, but not after the TR.

The reductions in blood pressure levels after a single exercise session is in agreement to the results obtained by other studies in which PEH after aerobic (i.e., treadmill or cycle ergometer) and resistance exercises, for normotensive and hypertensive subjects was observed (6,10,14,15,17,21,23,24). However, the main contribution was the demonstration that the decreased blood pressure induced by exercise may represent a protective mechanism for the cardiovascular system during real daily living activities, once blood pressure levels remained below those of the control session until the end of the work shift (R7h; Figure 1a–c).

During the CON session, the participants’ BP rose from 126.4/80.0 mm Hg at rest to 137.4/85.0 mm Hg at the end of the work shift. However, after TR or RE sessions, the BP remained below the CON and an increase in BP was also observed over the day period despite previous exercise. This increase in BP may be due to the higher activity of the sympathetic nervous system and the higher levels of catecholamines observed at the end of the afternoon, as evidenced by Linsell et al. (19) and Park et al. (31). Another possible explanation for the higher BP observed at the end of the workday may be due to the stress of working. In fact, there is evidence that employees have an increased BP and thus higher day-night BP differences as compared to unemployed individuals (35). Thus, despite any influence of the circadian cycle, it became clear from the present study that 20 minutes of either TR or RE were able to attenuate the subjects’ BP over the workday.

The hypotensive effects of aerobic exercise have been more intensively studied and documented than those of resistance exercise. Hagberg et al. (16) observed systolic BP PEH lasting for 2 hours and diastolic BP PEH lasting for 1 hour and 15 minutes on hypertensive subjects, after 45 minutes of running at 70% $V_{\text{O2\max}}$. In the present study, the PEH was observed
after only 20 minutes of aerobic exercise using a similar intensity (70–80% of the heart rate reserve). In comparison to the values obtained after resistance exercise, the treadmill running promoted a decrease in systolic BP that lasted longer, confirming the results of other studies (12,23,25).

However, despite of producing PEH of higher duration for systolic BP, the treadmill running did not yield any PEH of diastolic BP in relation to pre-exercise values (Figure 1b). The PEH of diastolic BP was observed only after resistance exercises (R15), with a lowering effect lasting 45 minutes after RE in relation to CON.

The results of the blood lactate response suggest a higher metabolic stress for RE. On the other hand, the aerobic exercise (TR) resulted in a higher double product suggesting an elevated cardiovascular stress in relation to RE (Figure 2). Thus, the mechanisms of PEH induction on those sessions may be different. The significant correlation between blood lactate after RE and BP decrease during postexercise recovery is in accordance to Crisafulli et al. (9), who verified a relationship between blood lactate accumulation and the decrease of the systemic vascular resistance and BP after exercise in athletes. Therefore, the metabolic stress of RE (i.e., higher blood lactate) may have a relationship to blood pressure reduction after this session.

The PEH observed after a single exercise session on the present study confirmed the results of other studies in normotensive subjects (4,10,11,14,15,24,37,38). Investigating the effects of resistance exercise in normotensive and hypertensive women, Fisher (11) verified a similar decrease in blood pressure after exercise for both groups. Similarly, Brown et al. (4) verified that 25 minutes of arm ergometry exercise, as well as resistance exercise sessions at 40% and 70% of 1RM, elicited the same hypotensive effect. These results corroborate with the findings of the present study, where 20 minutes of different exercise modes resulted in a similar PEH response.

The acute reductions on resting systolic BP between 9 and 13 mm Hg reported in the present study during exercise recovery in relation to CON (Figure 1a) are comparable to those elicited by chronic exercise program as presented by Cornelissen and Fagard (8). The reductions on resting blood pressure are relevant once hypertensive adults (45–47 years) present 3.9 times more chances to have a stroke (3). Also, a decrease of 10–12 mm Hg in systolic BP and 5–6 mm Hg in diastolic BP may reduce in ~38% this risk (7). It is possible to say that exercising in the morning to late morning may be particularly beneficial since exercise-induced hypotension blunts afternoon rises in blood pressure.

During all experimental sessions, eight participants were using beta-blockers agents, while seven were under treatment with angiotensin converting enzyme (ACE) inhibitors alone or in association to calcium-channel blockers. Both the TR (~70% of the predicted heart rate reserve or ~80% heart rate reserve from maximal graded exercise test) and the RE circuit sessions (20 repetitions at 40% of 1RM) were prescribed in accordance to guidelines for hypertensive subjects (1,2). Since the medications intake was the same in all experimental sessions, both the 1-Hour PEH (i.e., BP reduction in relation to pre-exercise resting), as well as the 7-Hour lowering effect on BP (i.e., a reduction observed in relation to control session) may be due to the exercise intervention. Moreover, Wilcox et al. (39) reported that exercise associated to medications, such as beta-blockers, did not impair PEH. In addition, more recently (27) it was verified in hypertensive women receiving captopril (i.e., ACE inhibitor) that a single bout of low-intensity resistance exercise induces similar PEH to other studies without medication. Since PEH is a phenomenon that has been considered clinically useful as a nonpharmacological treatment of hypertension and also occurs even under medication use, additional studies are necessary for a better comprehension about the interactions between exercise and antihypertensive medications.

The evidence of a protective effect of a single exercise session (treadmill running or resistance exercise) on the cardiovascular system of hypertensive subjects throughout their workday indicates that it is important to encourage physical exercise practicing to prevent or treat hypertension. Exercise interventions performed at the workplace, even for only 20 minutes as presented on this study, may also bring other important benefits such as an improvement in the quality of life and survival expectancy of hypertensive individuals, besides reducing the costs related to the treatment of hypertension.

In conclusion, when compared to pre-exercise resting, both 20 minutes of treadmill running and 20 minutes of resistance exercises resulted in PEH. However, the running exercise resulted in a longer PEH for SBP, while the hypotensive effect on DBP was observed only after resistance exercise, probably due to the higher metabolic stress. When compared to the control day without exercise, both exercise sessions yielded a significant reduction in blood pressure throughout 7 hours after exercise, even while the subjects maintained their regular occupational activities.

**Practical Applications**

The results from this study raise the possibility that just 20 minutes of acute exercise promotes postexercise hypotension (PEH) for a group of middle-aged (42.9 ± 1.6 years) with previous medical screening, and with history (2–3 years) of stage 1 hypertension. These exercise modes may be able to promote PEH to persons in the same history of hemodynamic conditions.

The PEH observed by these session models allowed the reduction in blood pressure throughout 7 hours after exercise, even with regular occupational activities. This phenomenon may contribute to reducing the use of medications, increasing longevity, and preventing risk factors associated to cardiovascular diseases. Also, these exercises seem to be a recommended nonpharmacological and less expensive treatment of hypertension. The benefits of PHE may be optimized if two
exercise sessions were conducted in the same day (during the morning and at the end of the afternoon).

Finally, 20 minutes of circuit model of resistance exercise, using 13 exercises with 20 repetitions at 40%IRM, promoted minor cardiovascular stress compared to treadmill running, and consequently higher cardiac protection. These results suggest that circuit resistance training may be an excellent and useful model for physical exercise prescription for hypertensive individuals. However, further research will be required to confirm all these applications, and to verify PEH in other resistance exercise intensities.

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