

Aftereffects of Exercise and Relaxation on Blood Pressure

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Objective: To study the acute aftereffects of exercise and relaxation, performed alone and in combination, on blood pressure (BP) measured at baseline and during stressful conditions.

Design: Clinical trial with comparison of groups and repeated measures in each group.

Setting: Exercise Hemodynamic Laboratory, University of São Paulo, Brazil.

Participants: Fourteen normotensive (NT) and 16 essential hypertensive (HT) subjects.

Interventions: Four random experimental sessions: relaxation (RX-20 min); exercise [EX-cycle ergometer, 53 min, 50% peak oxygen uptake (VO_2peak)]; exercise plus relaxation (EX + RX); and control (C-73 min rest). Measures were taken before and after interventions at baseline and during Stroop color test.

Main Outcome Measures: Auscultatory and plethysmographic BPs.

Results: Systolic and diastolic BPs decreased significantly after all the interventions. The decreases in both BPs were significantly greater after the EX + RX session, and were also greater in the HT (EX + RX session, $-10 \pm 1 / -7 \pm 1$ and $-15 \pm 2 / -8 \pm 1$ mm Hg for the NT and HT, respectively). During mental stress, systolic BP increased significantly and similarly after all the experimental sessions. Diastolic BP also increased significantly during stress; however, the increase was significantly greater after the RX session. At the end of the mental stress, diastolic BP was significantly lower after the EX (74 ± 3 mm Hg) and EX + RX (72 ± 3 mm Hg) sessions than after the C (79 ± 3 mm Hg) and RX (78 ± 3 mm Hg) sessions.

Conclusions: In NT and HT subjects, a single bout of exercise or relaxation has hypotensive effects, further enhanced by their

combination, and greater in the HT. Moreover, exercise performed alone or in combination with relaxation decreases systolic and diastolic BPs during mental stress.

Key Words: blood pressure, physical exercise, relaxation, hypertension

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Hypertension is a very prevalent and hazardous disease, because it is strongly related to cardiac (25% of them are due to hypertension), and encephalic (40% of them are due to hypertension) stroke deaths.^{1,2} Nonpharmacological approaches of treatments, such as physical exercise and relaxation, have gained physicians' attention, because they represent inexpensive and safe methods that result in the control or, at least, in a decrease of blood pressure (BP), without undesired side effects.¹⁻³

Physical exercise and relaxation represent opposite physiologic stimuli, because exercise leads to a hypermetabolic state,⁴⁻⁷ whereas relaxation leads to a hypometabolic one.^{8,9} However, both the conditions have chronic hypotensive effects,^{3,10-12} and they are usually combined in physical conditioning classes.¹³ Nevertheless, besides the chronic effects, it is also known that just 1 bout of dynamic exercise decreases BP during the recovery period.^{3,14-17} This phenomenon has been called postexercise hypotension, and has been reported to have clinical relevance.^{3,18} On the other hand, the acute aftereffects of relaxation, as well as of the combination between exercise and relaxation, on postintervention BP have not been investigated yet.

Nowadays, subjects are frequently exposed to stressful situations that lead to sympathetic activation and cardiovascular changes, such as heart rate (HR) and BP increases.^{14,19,20} Some studies have suggested that exercise^{14,19-22} and relaxation²³ might reduce these cardiovascular responses to stress. However, these data are not conclusive.

Thus, we hypothesized that exercise and relaxation would reduce BP during the postintervention period, and this hypotensive effect would be greater when these interventions were combined. Moreover, exercise and relaxation would blunt cardiovascular responses to stressful situations. All these effects would be observed in hypertensive (HT) and normotensive (NT) subjects,

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but they would be more evident in the HT subjects. To test these hypotheses, the aim of the present study was to investigate, in NT and HT subjects, the acute effects of exercise and relaxation in isolation and in combination on BP and HR measured after these interventions at baseline and during mental stress.

METHODS

Subjects

Fourteen NT (8 men and 6 women) and 16 HT (10 men and 6 women) nonobese subjects volunteered for this study and signed a written consent. The study was approved by the Human Subject Protection Committees of the Heart Institute (InCor), and the General Hospital, both from the Medical School, University of São Paulo.

All volunteers had their BP measured 3 times in each of 2 visits to the laboratory. Subjects were classified as NTs if the averages of all measurements were below 130/85 mm Hg for systolic/diastolic BPs.^{1,2} They were classified as HTs stages I and II, if the mean BPs were within the range of 140/90 and 179/109 mm Hg.¹ Subjects were excluded from the study if they were obese (body mass index ≥ 30 kg/m²) or presented any evidence of secondary hypertension, target organ damage, cardiovascular risk factors or cardiovascular disease, except for hypertension. Subjects were not receiving any antihypertensive medication during the experimental sessions, and previous treatment was discontinued 4 weeks before the beginning of the study. None of the volunteers was participating in any regular physical activity program, nor was any volunteer acquainted with the practice of relaxation. Smoking prevalence was similar between groups (1 HT, and 2 NT). Physical and cardiovascular characteristics of the subjects are presented in Table 1.

Peak oxygen uptake (VO₂peak) was measured directly by a metabolic cart (Medical Graphics Corporation—CAD/NET-2001, St Paul, MN) during a maximal progressive cardiopulmonary exercise test, performed on a cycle ergometer (Mijnhardt, Kem III, Bunnik, Holland) with a protocol of 30 W-increments every 3 minutes, until subjects were unable to continue. Tests were interrupted

due to physical fatigue, abnormalities in the electrocardiogram, or excessive BP increase.²⁴ Subjects with positive stress tests were excluded from the study.

Measurements

During the experimental sessions, BP was measured indirectly by auscultation, using a mercury sphygmomanometer. Moreover, before and during mental stress, BP was continuously measured, on a beat-by-beat basis, by finger plethysmography (OHMEDA, FINAPRES, Madison, WI). HR was measured by the ECG (Tecnológica Eletrônica do Brasil, SM300, São Paulo, SP, Brazil).

Interventions

Relaxation Protocol

The relaxation session lasted 20 minutes and was based on a Yoga technique called “shavasana.”^{8,25} During this intervention, the volunteers remained in the supine position, and tried to develop a state of conscious detachment from the external environment. To do so, they listened to a tape with 10 minutes of guided relaxation, followed by 10 minutes of silence.

Dynamic Exercise Protocol

The exercise session lasted 53 minutes. The volunteers were placed on a cycle ergometer (Mijnhardt, Kem III, Bunnik, Holland) for an initial 3 minutes warm-up period, which was followed by 45 minutes of exercise at 50% of VO₂peak, and 5 minutes of recovery on the cycle ergometer. The workload equivalent to 50% of VO₂peak was calculated by a linear regression between the VO₂ and the workload measured in the maximal progressive cardiopulmonary exercise test.

Experimental Protocol

All subjects were randomly submitted to 4 experimental sessions with a minimum of 4-day intervals: control (C), exercise (EX), relaxation (RX), and exercise plus relaxation (EX+RX). Subjects arrived at the laboratory after an overnight fast, and they were instructed to avoid caffeine and smoking before the experimental sessions. Moreover, they were asked to avoid sporadic exercise and alcohol ingestion for at least 24 hours before the experiments. The experimental design is shown in Figure 1.

In each session, subjects rested in the supine position for a 20-minute period (preintervention period-Pre), during which auscultatory BP and HR were measured every 5 minutes, and a mean value was calculated (excluding the first and the last measures). Then, interventions were initiated following a different protocol each, according to the experimental session: (a) EX—dynamic exercise protocol; (b) RX—relaxation protocol; (c) EX+RX—exercise followed by relaxation protocol, and (d) C—resting for 53 minutes on the cycle ergometer, and for 20 minutes in the supine position. After the interventions, subjects rested in the supine position for 90 minutes, which was considered the postintervention period. During this period, auscultatory

TABLE 1. Physical and Cardiovascular Characteristics of NT and HT Subjects

Group	NT	HT
N	14	16
Age (y)	39 ± 2	43 ± 1
Weight (kg)	69.9 ± 1.6	75.4 ± 2.5
Height (cm)	166 ± 2	168 ± 2
BMI (kg/m ²)	25.3 ± 0.4	26.7 ± 0.6
SBP (mm Hg)	120 ± 1	144 ± 2*
DBP (mm Hg)	74 ± 1	96 ± 1*
VO ₂ peak (mL kg ⁻¹ min ⁻¹)	33.7 ± 1.6	30.5 ± 1.7

Values are mean ± SE.

*Different from NT ($P < 0.05$).

BMI indicates body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.

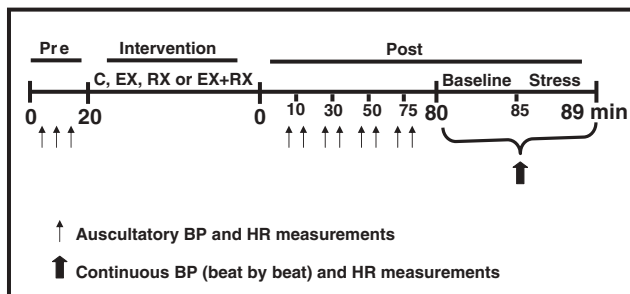


FIGURE 1. Design of the experimental sessions. BP, blood pressure, HR, heart rate, C, control, EX, exercise, RX, relaxation.

BP and HR were measured twice at 10, 30, 50, and 75 minutes, and a mean value was calculated for each stage.

Mental stress maneuver was conducted by Stroop color test²⁶ applied 80 minutes after the interventions. Briefly, a panel with the names of 3 colors written with letters in different colors was shown to the subjects, and they had to tell, as quickly as possible, the color of the letters without reading the words. This test was preceded by 5 minutes of baseline measurements, and lasted 4 minutes. BP and HR were continuously recorded. Mean values were calculated for the baseline period, and for each minute during the stress.

Statistical Analysis

In each group (NT and HT), BP and HR responses to the interventions were calculated by the difference between values measured at 10, 30, 50, and 75 minutes after the interventions, and values measured before them. Similarly, in each session, BP and HR responses to mental stress were calculated by the difference between values measured at 1, 2, 3, and 4 minutes of stress, and values measured before it. The comparison of the differences between groups and sessions was performed by a 3-way analysis of variance (ANOVA-STATISTICA for Windows, version 4.3, StatSoft, Inc, 1993, Tulsa, Oklahoma), including group (NT and HT) as between-group main factor, and experimental sessions (C, EX, RX, EX + RX) and stages (Pre, 10, 30, 50, and 75 or Baseline, 1', 2', 3', and 4') as repeated (within-subjects) factors. Newman-Keuls test was used for post-hoc comparisons, and a level of *P* < 0.05 was accepted as significant. Data are presented means ± SE.

RESULTS

As the order of the sessions was randomly assigned among the subjects in each group, 4 NT and 3 HT began the protocol with the C session, 4 NT and 4 HT with the EX session, 4 NT and 6 HT with the RX session, and 2 NT and 3 HT with the EX + RX session.

Preinterventions, systolic and diastolic BPs measured in the 4 experimental sessions are presented in Table 2. As expected, systolic and diastolic BPs were

TABLE 2. Auscultatory Systolic (SBP) and Diastolic (DBP) Blood Pressures Measured Preintervention in the C, EX, RX, and EX+RX Sessions in the NT and HT Subjects

	NT	HT
SBP (mm Hg)		
C	118 ± 3	144 ± 3*
EX	119 ± 2	144 ± 4*
RX	122 ± 1	144 ± 3*
EX + RX	121 ± 2	144 ± 2*
DBP (mm Hg)		
C	73 ± 2	94 ± 1*
EX	73 ± 2	94 ± 2*
RX	75 ± 2	95 ± 2*
EX + RX	74 ± 2	94 ± 1*

Values are mean ± SE.
*Different from NT (*P* < 0.05).

significantly higher in the HT than in the NT group, and they did not differ among the experimental sessions.

When systolic BP responses to interventions were analyzed, there was no significant interaction between the 3 factors. However, there was significant interaction between the factors: session and stage (*P* < 0.0001), and group and stage (*P* < 0.0001). Therefore, because of the significant interaction between the factors session and stage, data from the NT and HT groups were combined and are shown in Figure 2A. Subsequent analysis demonstrated that, independent of the group (NT or HT), systolic BP decreased significantly after all the interventions, and this reduction was significantly greater after the EX, RX, and EX + RX sessions than after the C session. Moreover, the decrease in systolic BP observed in the EX + RX session was significantly greater than those observed after the EX and RX sessions. Because of the significant interaction between the factors group and stage, data from all the sessions were combined, and are shown in Figure 2B. Subsequent analysis revealed that, independent of the session (C, EX, RX, or EX + RX), systolic BP decreases were significantly greater in the HT than in the NT group.

Diastolic BP presented results similar to the ones observed for systolic BP. There was no significant interaction between the 3 factors; however, there was significant interaction between the factors: session and stage (*P* < 0.0001), and group and stage (*P* = 0.0230). Because of the interaction between session and stage, data from the NT and HT groups were combined and are shown in Figure 3A. Subsequent analysis revealed that, independent of the group (NT or HT), diastolic BP increased slightly after the C session, and decreased significantly after all the other sessions. Diastolic BP decrease was significantly greater after the combined EX + RX session than after either the EX or RX sessions. Because of the significant interaction between the factors group and stage, data from all the sessions were combined, and are shown in Figure 3B. Subsequent analysis revealed that, independent of the session (C, EX,

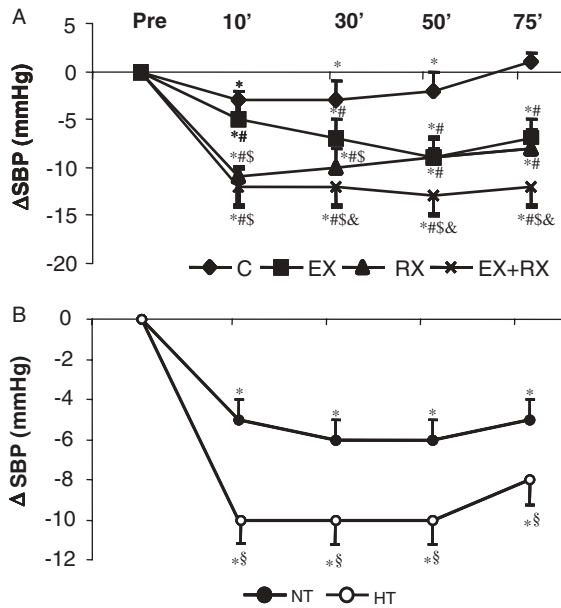


FIGURE 2. Systolic blood pressure responses (Δ SBP) measured before (Pre), and at 10, 30, 50, and 75 minutes after the interventions. A, Because of the significant interaction between the factors session and stages in the 3-way analysis of variance, data from normotensive (NT) and hypertensive (HT) groups were combined and shown for the control (C), exercise (EX), relaxation (RX), and exercise plus relaxation (EX+RX) sessions. B, Because of the significant interaction between the factors group and stage in the 3-way analysis of variance, data from all the experimental sessions were combined and shown for the NT and HT groups. Values are mean \pm SE; *different from Pre ($P < 0.05$); #different from control ($P < 0.05$); \$different from EX ($P < 0.05$); & different from RX ($P < 0.05$); §different from NT group ($P < 0.05$).

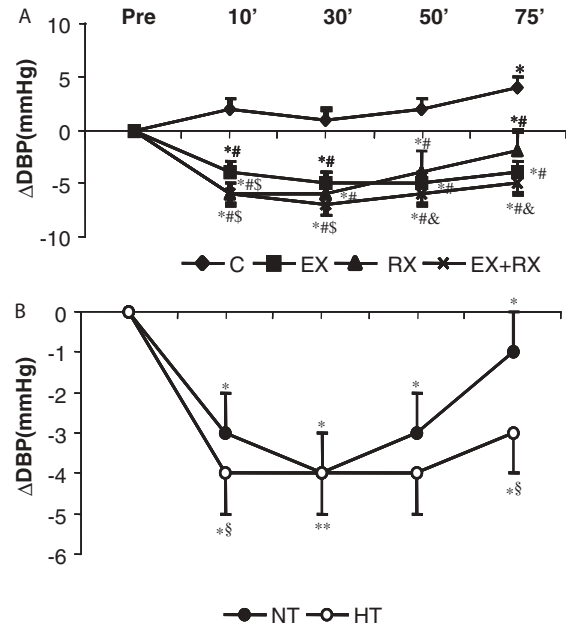


FIGURE 3. Diastolic BP responses (Δ DBP) measured before (Pre), and at 10, 30, 50, and 75 minutes after the interventions. A, Because of the significant interaction between the factors session and stages in the 3-way analysis of variance, data from normotensive (NT) and hypertensive (HT) groups were combined and shown for the control (C); exercise (EX), relaxation (RX), and exercise plus relaxation (EX+RX) sessions. B, Because of the significant interaction between the factors group and stage in the 3-way analysis of variance, data from all the experimental sessions were combined and shown for the NT and HT groups. Values are mean \pm SE; *different from Pre ($P < 0.05$); #different from C ($P < 0.05$); \$different from EX ($P < 0.05$); &different from RX ($P < 0.05$); §different from NT group ($P < 0.05$).

RX, or EX + RX), diastolic BP decreases were greater in the HT than in the NT group.

Response to Mental Stress

Systolic BP measured before the mental stress maneuver was significantly lower after the EX + RX than after the C session (122 ± 4 vs. 131 ± 5 mm Hg, $P < 0.05$) and, as expected, it was significantly higher in the HT than in the NT group (135 ± 4 vs. 117 ± 4 mm Hg, $P < 0.05$). Analysis of systolic BP changes during mental stress showed a significant interaction only between the factors: group and stage ($P = 0.0080$). Thus, for subsequent analysis, results from all the sessions were combined and are shown in Figure 4. Systolic BP increased significantly during stress in both groups; however, this increase was significantly greater in the HT than in the NT group.

Diastolic BP measured before the mental stress was significantly lower after all the experimental sessions than after the C session (EX = 68 ± 3 , RX = 70 ± 2 , and EX + RX = 68 ± 2 vs. C = 74 ± 3 mm Hg, $P < 0.05$). As expected, it was significantly higher in the HT than in the

NT group (76 ± 2 vs. 64 ± 3 mm Hg, $P < 0.05$). Analysis of diastolic BP changes during the mental stress maneuver showed a significant interaction only between the factors: session and stage ($P = 0.0200$). Thus, for subsequent analysis, data from the NT and HT groups were combined and are shown in Figure 5. Independent of the group (NT or HT), diastolic BP increased significantly during stress. However, diastolic BP increase was significantly greater after the RX than after all the other sessions. At the end of mental stress, diastolic BP was significantly higher after the C and RX sessions (C = 79 ± 3 and RX = 78 ± 3 mm Hg, $P < 0.05$) than after the EX and EX + RX (EX = 74 ± 3 and EX + RX = 72 ± 3 mm Hg) sessions.

DISCUSSION

The main findings of the present study were: (1) both exercise and relaxation reduced systolic and diastolic BPs during the postintervention period; (2) this hypotensive effect was greater in the HT than in the NT subjects; (3) the hypotensive effects of exercise and relaxation were

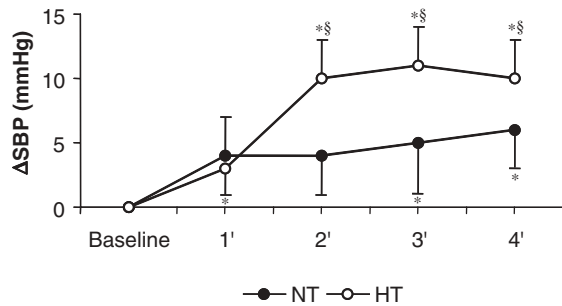


FIGURE 4. Systolic blood pressure response (Δ SBP) measured at baseline and at 1, 2, 3, and 4 minutes of mental stress in the normotensive (NT) and hypertensive (HT) groups. Because of the significant interaction between the factors group and stage in the 3-way analysis of variance, data from all the experimental sessions were combined. Values are mean \pm SE; *different from baseline ($P < 0.05$); §different from NT group ($P < 0.05$).

enhanced by their combination; (4) previous relaxation increased diastolic BP response to mental stress; (5) previous exercise did not change systolic nor diastolic BP responses to mental stress; (6) the combination between exercise and relaxation prevented the enhanced diastolic BP response to stress promoted by relaxation alone; and (7) exercise performed alone or in combination with relaxation decreased diastolic BP levels during mental stress.

As expected, a single bout of dynamic exercise reduced systolic and diastolic BPs during the recovery period in both, the NT and HT subjects.^{3,14-16,18,27} This hypotensive effect was already observed 10 minutes after the end of the exercise bout, and lasted for at least 80 minutes. Decreases in systolic/diastolic BPs were significantly greater in the HT subjects, and their greatest values were $-5 \pm 1 / -4 \pm 1$ and $-11 \pm 2 / -7 \pm 1$ mm Hg for NT and HT groups, respectively.

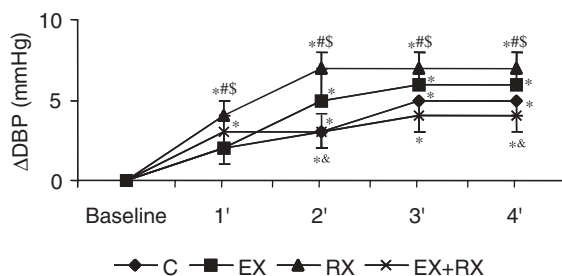


FIGURE 5. Diastolic BP responses (Δ DBP) measured at baseline and at 1, 2, 3, and 4 minutes of mental stress in the 4 experimental sessions: control (C), exercise (EX), relaxation (RX), and exercise plus relaxation (EX+RX). Because of the significant interaction between the factors session and stage in the 3-way analysis of variance, data from normotensive (NT) and hypertensive (HT) groups were combined. Values are mean \pm SE; *different from baseline ($P < 0.05$); #different from C ($P < 0.05$); §different from EX ($P < 0.05$); &different from RX ($P < 0.05$).

Similar to exercise, acute relaxation also promoted postintervention systolic and diastolic BP decreases in the NT and HT subjects. To our knowledge, this is the first controlled study to show this acute hypotensive effect of relaxation. In fact, most of the previous researches addressed the chronic effects of relaxation.^{10,11,28-31} The only other study³² that addressed the acute aftereffects of relaxation was performed on cardiac patients, who might have parasympathetic disautonomy,^{33,34} and thus a different BP response to relaxation. In the present investigation, BP decrease observed after the relaxation was similar to the one observed after the exercise, and it was greater in the HT subjects. In fact, the greatest systolic/diastolic BP decreases were $-6 \pm 1 / -6 \pm 1$ mm Hg, and $-12 \pm 1 / -7 \pm 1$ mm Hg in the NT and HT groups, respectively.

An interesting new finding of this study is that the combination of exercise and relaxation led to a greater postintervention BP decrease than exercise or relaxation alone. In fact, the greatest decreases in systolic/diastolic BPs observed after this combination were $-10 \pm 1 / -7 \pm 1$ mm Hg and $-15 \pm 2 / -8 \pm 1$ mm Hg in the NT and HT groups, respectively. Once again, the hypotensive effect was greater in the HT subjects.

Altogether, our results showed that exercise and relaxation, especially when performed together, had important acute postintervention hypotensive effects on NT subjects and even greater effects on HT subjects. These findings show the clinical relevance of these acute interventions, and support their combined application in physical conditioning classes aiming at health improvement.

Another important new finding of this paper was the effect of previous interventions on BP responses to mental stress. As expected mental stress increased systolic and diastolic BPs,^{14,19,35} and these increases were greater in the HT subjects, which is in accordance to the greater BP reactivity usually observed in these patients.²⁰ The execution of a single bout of exercise did not change systolic nor diastolic BP reactivity to stress. Thus, after exercise, diastolic BP that was already lower before the stress, remained lower throughout it, showing that postexercise hypotensive effects are also sustained during stressful situations. On the other hand, when relaxation was performed alone before stress, diastolic BP response to it was enhanced, and the lower diastolic BP level observed before the stress, became similar to control during it, showing that the diastolic hypotensive effect produced by relaxation is lost under stressful conditions. It is interesting to observe, however, that if exercise was executed before relaxation, as in the EX+RX session, diastolic BP increase during stress was not enhanced, and BP was maintained lower than after the C session, before and during the stress. This result shows that previous exercise prevents the enhanced diastolic BP response to stress produced by relaxation.

Results from the present study show that exercise has many acute beneficial aftereffects that may have clinical significance. Besides decreasing systolic and

diastolic BPs in a control condition, it also decreases them in stressful situations. Moreover, when combined with relaxation, it prevents the exacerbated diastolic BP response to stress induced by relaxation, maintaining BP levels lower. These findings support the application of exercise, alone or in combination with relaxation, in the nondrug treatment of hypertension.

The mechanisms responsible for BP reductions after exercise and relaxation are beyond the scope of the present investigation. However, a decrease in sympathetic activity might be involved, because others¹⁸ and ourselves^{15,16} have observed a sympathoinhibition after exercise. Similarly, as relaxation is characterized by a decrease in sympathetic activity,^{9,36} this effect might persist after the end of intervention, leading to the decrease in BP. It is interesting to point out, however, that if this mechanism is correct, the present results suggest that sympathoinhibition produced by exercise is more consistent than that produced by relaxation, as the latter is lost under mental stress. In fact, these mechanisms should be investigated by future researches.

Limitations

The experimental design of the study presented a difference in the time of measurements after exercise in the EX and EX+RX sessions; in other words, post-intervention data acquisition began immediately after the end of the exercise bout in the EX session, but 20 minutes after it in the EX+RX session. Thus, it should be questioned if the greater decrease in BP observed after the EX+RX session was not due to the longer period of time after exercise. Nevertheless, this does not seem to be the case because systolic BP decreases observed at 10 and 30 minutes after the EX+RX session were significantly greater than those observed at 30 and 50 minutes after the EX session, respectively, which corresponded to similar periods of time after the end of the exercise bout. Thus, the greater BP decrease observed after the EX+RX session might be attributed to the combination of exercise and relaxation, and not to the period of time after exercise.

CONCLUSIONS

In NT and HT subjects, a single bout of aerobic exercise or relaxation reduces systolic and diastolic BPs after their execution. These hypotensive aftereffects are similar in magnitude, and are greater in HT subjects. Moreover, the combination of exercise and relaxation enhances their hypotensive aftereffects.

Previous exercise reduces BP levels during stress, and prevents the relaxation-induced enhancement in diastolic BP response to stress.

Thus, previous exercise, performed alone or in combination with relaxation, reduces systolic and diastolic BPs not only under baseline conditions but also during stressful situations.

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