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The Effects of Two Aerobic Training Intensities on Ambulatory Blood Pressure in Hypertensive Patients: Results of a Randomized Trial

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ABSTRACT. The effect of different intensities of aerobic exercise on blood pressure remains uncertain. The goal of this trial was to compare the effect of two different levels of aerobic physical training on 24-hour ambulatory blood pressure. In this double-blind parallel-group trial, 28 sedentary hypertensive patients (mean diastolic blood pressure of 90 to 104 mmHg) were randomly assigned to 10 weeks of physical training at 20% (Group I) or 60% (Group II) of their maximal workload on a cycle ergometer (mean load of 32 and 85 watts, respectively). Maximal oxygen consumption was estimated by the time spent on a mechanical braked Monark bicycle (Monark, Sáo Paulo, Brazil). Indexes of physical fitness were determined by cycle ergometer tests before and after the experimental period. The principal outcome variable was mean 24-hour ambulatory blood pressure. Mean 24 hour systolic blood pressure fell from 137.2 ± 14.9 to 135.2 ± 12.7 mmHg in Group I and from 144.4 ± 13.3 to 138.6 ± 12.9 in Group II (mean between group difference of –2.1 mmHg, P = 0.479, adjusted for baseline blood pressure). Mean diastolic blood pressure fell from 9.21 ± 10.0 to 89.3 ± 7.7 mmHg in Group I and from 93.3 ± 5.8 to 90.6 ± 6.8 mmHg in Group II (mean adjusted difference of –0.06, P = 0.765). Nighttime blood pressure did not change in either group. Across all participants, a reduction in systolic blood pressure was significantly associated with improved physical fitness as manifest by increased physical work capacity at heart rate of 130 bpm (PWC_{130}), increased systolic blood pressure at PWC_{130}, and decreased maximum heart rate measured during the cycle ergometer test We conclude that aerobic training programs at 20% and 60% of the maximum work capacity have similar effects on ambulatory blood pressure. J CLIN EPIDEMIOL 52;7:637–642, 1999. © 1999 Elsevier Science Inc.

KEY WORDS. Hypertension, exercise, aerobic training, ambulatory blood pressure monitoring

INTRODUCTION

Hypertension, a major risk factor for cardiovascular disease, remains highly prevalent in both industrialized and developing countries [1–3]. Several nonpharmacological therapies (weight loss, reduced salt intake, moderate alcohol consumption, and aerobic exercise) are recommended as means to prevent or treat hypertension. Among them, aerobic training is unique because it is not a nutrition-based strategy.

Several controversies surround the use of exercise as a means to reduce blood pressure [4,5]. although there is a general consensus that aerobic training reduces blood pressure, available evidence has several limitations. The inverse association between blood pressure and physical activity detected in observational studies may in part be explained by residual confounding from a healthier lifestyle. Furthermore, most experimental studies have at lease one major shortcoming, including lack of control group, imbalance in baseline characteristics, small sample sizes, unblinded measurements of blood pressure, and no control for cointervention effects. A second controversy pertains to the level of exercise necessary to reduce blood pressure [6]. Most trials have studied moderate-to-high levels of aerobic training, for example, exercising at 50%–80% of maximal work capacity. Whether lower levels of physical activity reduce blood pressure is an important research issue with enormous clinical and public health significance.

The objective of this report is to present the results of a randomized, double-blind, clinical trial that compared the effects of two aerobic training intensities on 24-hour ambulatory blood pressure in patients with hypertension.

METHODS

The trial was carried out at the Hypertension Unit of the Hospital de Clínicas de Porto Alegre. The project was ap-

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proved by the hospital's Institutional Review Board. All participants gave written informed consent.

Study Participants

Participants were recruited from the hypertension outpatient clinic and through advertisements in local newspapers. To be eligible for this trial, individuals had to be sedentary, defined by the nonengagement in sports and the absence of regular exercise in the previous year. They also could not have any contraindication to exercise on a cycle ergometer. In addition, they had to have a mean baseline diastolic blood pressure of 90 to 104 mmHg (the average of six readings, i.e., two reading per day taken on three different days at 7– to 10–day intervals). Individuals on drug therapy had to undergo a period of medication withdrawal of at least 1 month prior to enrollment. About one third of the volunteers screened were enrolled in the trial. Systolic blood pressure was recorded as the first Korotkoff sound, and diastolic blood pressure, as the fifth Korotkoff sound, after participants rested 5 minutes.

Measurements

The patients performed a maximal treadmill exercise test to rule out asymptomatic coronary heart disease. They also performed a maximal exercise test on a mechanically braked cycle ergometer before and after the intervention period to evaluate functional capacity. Functional capacity was estimated from the heart rate at the maximal workload, percentage of the maximal heart rate, test duration, maximal workload, physical work capacity at heart rate of 130 bpm (PWC_{130}), systolic blood pressure at PWC_{130}, and systolic blood pressure at the peak of exercise.

Maximal oxygen consumption was estimated by the time spent on a mechanical braked Monark bicycle using the American College of Sports Medicine's protocol [7]. The initial workload was set at 0.5 kg. Increments of 0.5 kg were added every 2 minutes. The subject was encouraged to continue exercising until exhaustion. The load recorded at that time was taken as the individual's maximal workload. The electrocardiogram was monitored continuously; blood pressure and heart rate were recorded at the end of each stage.

Ambulatory blood pressure monitoring was obtained at baseline, prior to randomization, and again in the first week after the end of intervention. On a typical workday, blood pressure measurements were obtained with a model PIV device (Del-Mar Avionics, Irvine, CA) at 10-minute intervals between 7:00 AM and 11:00 PM and at 15-minute intervals between 11:00 PM and 7:00 AM. The comparability of blood pressure determined by this device with standard manual measurements had been previously demonstrated [8]. Systolic blood pressure values lower than 50 or higher than 225 mmHg, and diastolic blood pressure values lower than 30 or higher than 150 mmHg, were excluded from analysis; a tracing was considered adequate if ≥90% of measurements did not exceed these limits. Twenty-four-hour urinary sodium excretion, the sum of seven skinfold thicknesses (triceps, biceps, subscapular, suprailiac, abdominal, thigh, and mid-axillary), and body mass index were determined before and after the intervention period.

Exercise Programs

Once a screened volunteer was eligible and expressed interest to participate, he or she was randomly allocated to one of two training programs, each lasting 10 weeks. The assignments were placed in consecutive and sealed envelopes, with group codes based on random numbers, and with blocks of four subjects. Group I trained at 20% of maximum workload and Group II at 60% of workload. Both participants and blood pressure technicians were masked to group assignment.

Participants exercised three times per week for 10 weeks, from 2:00 to 3:00 PM, under the supervision of trained personnel. Each exercise session began with a 5-minute warm-up period, followed by 30 minutes of exercise at the determined workload on the cycle ergometer and a 5-minute cool-down period. Prior to exercise session and twice every 15-minutes during the exercise session on the cycle ergometer, blood pressure was measured with a standard aneroid sphygmomanometer and heart rate by wrist palpation. The patients were instructed to maintain their usual dietary habits during the trial, that is, not change their salt or alcohol intake.

Statistical Analysis

The trial was designed to test the null hypothesis that there was no between group difference in blood pressure change. A sample size of 32 patients (16 assigned to each group) was estimated to provide 80% power at alpha = 0.05 (two-tailed) to detect a 5-mmHg difference in ambulatory diastolic blood pressure assuming a standard deviation of 5 mmHg [9].

Within each group, changes (deltas) in blood pressure, weight, body mass index, the sum of seven skinfolds, 24-hour urinary sodium excretion, and indexes of physical fitness measured in the treadmill test were calculated by subtracting the baseline values from the values measured after the training period. Between groups differences in these variables were calculated by subtracting the change observed in the low-intensity exercise group from the change observed in the higher-intensity group.

Analyses were conducted on an "intention to treat" basis. Between group differences were tested by *t* tests for independent samples; the corresponding 95% confidence intervals were calculated. Analysis of covariance was used to adjust for baseline blood pressure. To determine whether change in blood pressure was associated with changes in fitness, we calculated Pearson correlation coefficients be-

TABLE 1. Initial characteristics of the groups training at 20% (Group I) and 60% (Group II) of maximal workload (Means ± SD or *n* [%] when appropriate)

Variables	Group I (n = 14)	Group II (n = 14)	P Value
Age (y)	52.2 ± 9.2	47.2 ± 9.2	0.20
Male	8 (53.3)	7 (46.7)	0.70
Body mass index (kg/m^2)	28.9 ± 6.5	26.1 ± 4.8	0.30
Sum of seven skinfolds (mm)	158.4 ± 58.8	129.7 ± 65.8	0.23
Previous use of antihypertensive drugs	8 (61.5)	7 (50.0)	0.87
Current drinkers	8 (57.1)	4 (28.6)	0.25
Smokers	2 (14.3)	3 (21.4)	0.62
24-hour sodium excretion (mEq/day)	102.7 ± 59.0	112.4 ± 52.3	0.66
Mean clinic SBP (mmHg)	155.9 ± 13.9	153.5 ± 14.9	0.67
Mean clinic DBP (mmHg)	98.4 ± 4.7	96.9 ± 4.8	0.43
Mean clinic HR, resting (bpm)	83.3 ± 10.3	80.8 ± 9.1	0.50

Abbreviations: DBP = diastolic blood pressure; HR = heart rate; SBP = systolic blood pressure.

tween change in blood pressure and change in indices of physical fitness.

RESULTS

The baseline features of the experimental groups are presented in Table 1. Participants tended to be middle-aged. Both genders were well represented. On the basis of clinic measurements, mean systolic and diastolic blood pressure fell within the stage I category of hypertension.

Two participants abandoned the conditioning sessions after 5 weeks (both of them in the higher-workload group). However, each had follow-up data collected at the end of the experimental period and were included in the analysis. An analysis performed without these participants did not change substantially the results and are not presented. The remaining participants attended 93% of the expected number of conditioning sessions.

The exercise intensity actually achieved in the two groups differed significantly, as indicated by mean heart rate, percent maximal heart rate, and workload during the intervention period (Table 2). Despite the low intensity of the training program for Group I, 12 (85.7%) participants achieved a mean heart rate ≥ 100 bpm during the intervention period. Here, on average, Group I participants exercised at 68.7% of the maximal heart rate. This intensity of training usually corresponds to a moderate intensity of training, but in this trial was reached by exercising on the cycle ergometer at an average workload of 21.7%. Within each group, body weight, body mass index, the sum of seven skinfolds' thickness and 24-hour urinary sodium excretion did not change significantly during the training period (data not shown).

Each trial participant had adequate baseline and follow-up ABP monitoring tracings. Mean 24-hour systolic blood pressure fell from 137.2 ± 14.9 to 135.2 ± 12.7 mmHg in the group training at 20% of the maximum workload and from 144.4 ± 13.3 to 138.6 ± 12.9 mmHg in the higher-intensity group (Table 3). Mean 24-hour diastolic blood pressure fell from 92.1 ± 10.0 to 89.3 ± 7.7 mmHg in the lower-intensity group and from 93.3 ± 5.8 to 90.6 ± 6.8 mmHg in the higher-intensity group. The within-group change in 24-hour ABP occurred as result of a decrease in daytime blood pressure, because nighttime blood pressure did not change in either group (Table 3). Between-group differences in post-training blood pressure were not statistically significant before and after adjusting for the corresponding baseline blood pressure (Table 3). At the end of the intervention period, the pattern of circadian blood pressure was

TABLE 2. Training characteristics of the groups exercising at 20% (Group I) and 60% (Group II) of maximal workload (Means ± SD or *n*[%], when appropriate)

Variables	Group I	Group II	P value
HR training (bpm)	117.4 ± 17.3	147.7 ± 12.3	<0.001
Participants training at HR ≥ 130 bpm	6 (42.9)	14 (100)	0.002
% of maximal HR	68.7 ± 6.5	84.1 ± 4.3	<0.001
Loads (watts)	32.4 ± 16.9	85.2 ± 22.3	<0.001
% of maximal workload (watts)	21.7 ± 1.2	58.5 ± 1.4	<0.001

Abbreviations: HR = heart rate

TABLE 3. Ambulatory blood pressure (mmHg) monitoring at baseline and after training (means ± SD), with the corresponding deltas (95% confidence intervals), by group

Variables	Group	Before	After	Adjusted[a]	P[b]	Delta[a]
24-hour SBP	Train 20%	137.2 ± 14.9	135.2 ± 12.7	135.8	0.479	−2.1 (−8.0 to 3.8)
	Train 60 %	144.4 ± 13.3	138.6 ± 12.9	137.9		
SBP-day†	Train 20 %	141.3 ± 13.3	137.8 ± 12.9	138.7	0.470	−2.2 (−8.4 to 4.0)
	Train 60%	149.4 ± 13.0	141.7 ± 13.9	140.9		
SBP-night‡	Train 20%	124.6 ± 13.8	127.8 ± 12.6	128.5	0.925	−0.4 (−8.3 to 7.5)
	Train 60%	129.4 ± 17.1	129.6 ± 11.9	128.9		
24-hour DBP	Train 20%	92.1 ± 10.0	89.3 ± 7.7	89.7	0.765	+0.6 (−3.6 to 4.9)
	Train 60%	93.3 ± 5.8	90.6 ± 6.8	90.3		
DBP-day†	Train 20%	94.9 ± 10.1	91.6 ± 8.3	92.2	0.856	+0.4 (−4.2 to 5.0)
	Train 60%	96.5 ± 6.1	93.1 ± 7.7	02.6		
DBP-night‡	Train 20%	83.3 ± 10.1	82.6 ± 7.3	82.7	0.363	+2.1 (−2.6 to 6.8)
	Train 60%	83.6 ± 8.1	84.9 ± 8.6	84.8		

Abbreviations: DBP = diastolic blood pressure; SBP = systolic blood pressure.
[a]Adjusted for the respective baseline blood pressure.
[b]Analysis of covariance, adjusting for baseline blood pressure.
†Day is defined as 7:00 AM to 23:00 PM.
‡Night is defined as 23:00 PM to 7:00 AM.

similar in both groups (Figure 1). Standard systolic and diastolic blood pressures, measured at rest in the seated position prior to treadmill test, decreased by 9.1 and 6.9 mmHg, respectively, in Group I and by 15.4 and 7.9 mmHg in Group II. Again, only within-group changes reached statistical significance.

Despite the observed differences in training intensities, both groups showed similar changes in cardiorespiratory fitness. Among the various indexes measured in treadmill tests, test duration and maximal workload increased in both groups. There was also a trend toward increased and physical work capacity at heart rate of 130 bpm (data not shown).

Across all participants, the change in physical work capacity at heart rate of 130 bpm (PWC_{130}), the change in systolic blood pressure at PWC_{130}, and the change in maximum heart rate were associated with a reduction in ambulatory systolic blood pressure (Table 4). Hence, improvements in fitness appeared to be associated with reductions in systolic blood pressure. There were no consistent correlates between change in diastolic blood pressure and change in fitness.

DISCUSSION

In this randomized clinical trial, 10 weeks of aerobic training at levels corresponding to the lower and higher limits of recommended aerobic exercise training [10] led to similar reductions in blood pressure in patients with mild hypertension. The similar blood pressure decrease observed in the two experimental groups favor two interpretations, that is, that both intensities of exercise had an antihypertensive effect or that neither had an effect. Observations that both groups had similar changes in cardiorespiratory fitness and that improved physical fitness was highly correlated with a decrease in systolic blood pressure support in the first interpretation. Conversely, observations from other studies that office and ambulatory blood pressure fall between two points in time even without an active intervention are in accordance with the second interpretation [11–13]. Such blood pressure reductions may be attributed to the regression to the mean [14] or to an arousal effect from initial readings. The possibility that such phenomenon could have happened even with ambulatory blood pressure monitoring is highlighted by observation that within groups, daytime but not nighttime ambulatory blood pressure fell in both exercise groups.

Alternatively, the study may have had insufficient power to detect a small change in blood pressure across groups. In this trial, there was a nonsignificant 2.1 mmHg reduction in systolic ambulatory blood pressure attributable to the higher intensity of training. While such a difference may have public health significance, its clinical significance is debatable and would likely be insufficient to support recommendations to exercise at a high-intensity level. Besides, the differences in favor of the higher intensity of exercise were restricted mainly to daytime systolic blood pressure and were opposite in the case of diastolic blood pressure.

The groups may also differed in terms of some anthropometric, behavioral, and physical baseline characteristics, despite the absence of statistical significance. These differences may just reflect random variation. Still, it is improbable that such differences could have influence the results, as the distribution of potential confounders was inconsistent and did not appear to affect one group differentially.

Among the strengths of this study are the "intention to treat" approach, the control for the effects of cointervention, and the relatively long periods of training and observation. It is doubtful that longer periods of training period could demonstrate a more intense effect, because many pre-

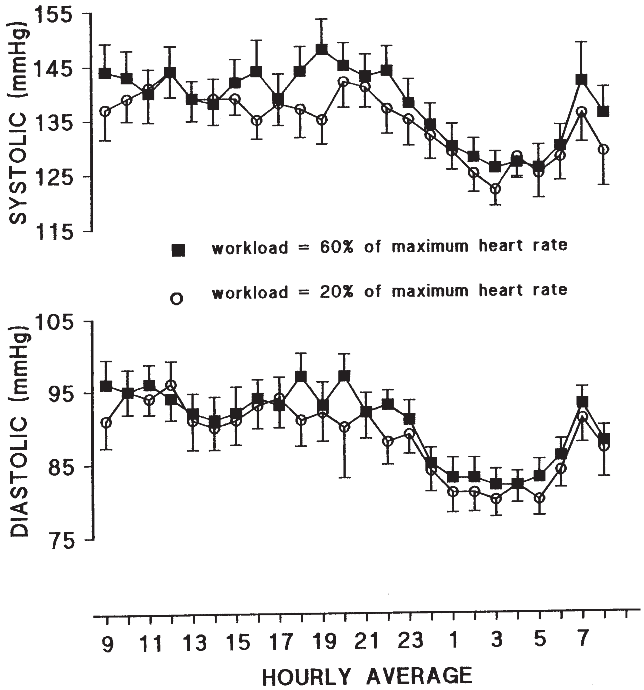

FIGURE 1. Results of the 24-hour ABP done after 10 weeks of physical training.

vious trials that had shown a beneficial effect of exercise were of even shorter duration [4].

One potential shortcoming of the present study is the indirect determination of the VO_2. Maximal work capacity was used as an indicator of maximal oxygen uptake because we could not measure this variable directly. The indirect measurement of VO_2 could have result in a biased assessment of fitness, both at baseline and after the conditioning sessions. In this case, the intensity of exercise done by the two groups could be not so different as originally planned, explaining at least in part the similarity of results. However, a close relationship between the two methods of measurement of VO_2 has been demonstrated previously [15]. Because cardiac output is equal to the product of stroke volume and heart rate, VO_2 max is directly related to heart rate. Considering that VO_2 max cannot be exceeded despite an increase in power output, a demonstration of the VO_2 plateau against heart rate is a valid demonstration of VO_2 max. Anyway, the groups exercised within quite different ranges of work, demonstrating that the intensity of exercise was definitely different.

A sound demonstration of an antihypertensive effect of aerobic exercise programs is still lacking. The shortcomings of most studies have been stressed [5]. Even in a more recent trial [16], both patients and investigators were unblinded, and two treatments were employed (exercise and antihypertensive drug therapy). In the trial of Cox *et al.* [17], an effect of exercise was only detectable in association with weight control. A deficiency present in many studies is the absence of a placebo intervention, which is effective in some hypertensive patients, as shown in drug trials [18]. The effects attributed to exercise may indeed be produced by the procedures followed to deliver it, such as repeated contact with the research team and the frequent measurement of physical variables (cointervention). Still, it is important to recognize the potential for misleading, or biased, results from meta-analysis of exercise trials. This concern results from the substantial heterogeneity in study design, particularly the population under study and the type, duration, and intensity of interventions [19]. Furthermore, the psychological expectation of benefits from treatment is certainly strong. In a trial with a design similar to that used in the present study [20], no clinically significant difference in ambulatory blood pressure was observed among the experimental groups.

In conclusion, a program of aerobic training at 60% of the maximum work capacity was no better than a program of training at 20% to lower blood pressure. In view of the possibilities that aerobic training may have limited effects on blood pressure, and, alternatively, that both low- and high-intensity training may substantially reduce blood pressure, a high priority for research on the effects of exercise

TABLE 4. Correlation coefficients (Pearson) between change in fitness measurements and change in ambulatory blood pressure across all study participants[a]

	Delta of test duration	Delta PWC 130 watts	Delta SBP at 130 bpm	Delta maximum workload	Delta maximum heart rate
Delta systolic 24 h	+0.27	–0.49*	–0.47**	+0.24	–0.36
Delta systolic day	+0.35	–0.48*	–0.42**	+0.36	–0.25
Delta systolic night	+0.06	–0.28	–0.38**	–0.03	–0.43**
Delta diastolic 24 h	+0.28	–0.01	+0.14	+0.35	+0.31
Delta diastolic day	+0.29	–0.05	+0.12	+0.39**	+0.32
Delta diastolic night	+0.22	+0.09	+0.15	+0.20	+0.18

Abbreviations: PWC 130 = physical work capacity at heart rate of 130 bpm.
[a]Deltas: pretraining values subtracted from post-training values.
*P < 0.01
**P < 0.05

should be the conduct of a sufficiently large clinical trial testing the impact on blood pressure of several intensities of aerobic training in comparison to a nonexercise control group.

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