How Much Exercise Is Required to Reduce Blood Pressure in Essential Hypertensives: A Dose–Response Study

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Background: Regular aerobic exercise is widely recommended for essential hypertensives. However, it is not clear how much exercise is needed to reduce blood pressure (BP).

Methods: The dose–response relation of exercise training and BP was determined using an 8-week exercise intervention study involving 207 untreated subjects with stage 1 or 2 essential hypertension. Subjects were divided into five groups based on the duration and frequency/week of exercise (sedentary control, 30 to 60 min/wk, 61 to 90 min/wk, 91 to 120 min/wk, and >120 min/wk). Age, gender, height, body mass, body mass index, dietary intake, and baseline BP were not different among the groups.

Results: Both systolic and diastolic BP at rest did not change in the nonexercising control group. All four exercise groups demonstrated significant reductions in both systolic and diastolic BP at rest. The magnitude of reductions in systolic BP was greater in the 61 to 90 min/wk group compared with the 30 to 60 min/wk group. There were no greater reductions in systolic BP with further increases in exercise volume. The magnitude of reductions in diastolic BP was not significantly different among four exercise groups. There were no obvious relations between exercise frequency per week and the magnitude of BP decreases with exercise training.

Conclusions: In previously sedentary hypertensive subjects, clinically significant decreases in BP can be achieved with relatively modest increases in physical activity above sedentary levels and that the volume of exercise required to reduce BP may be relatively small that should be reasonably attainable by a sedentary hypertensive population. Am J Hypertens 2003;16:629–633 © 2003 American Journal of Hypertension, Ltd.

Key Words: Hypertension, exercise therapy, intervention study.

Hypertension is an important determinant of the incidence of coronary heart disease, stroke, congestive heart failure, renal failure, and peripheral vascular disease.[1] Both the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure[1] and the World Health Organization[2] recommend regular aerobic exercise as part of an initial lifestyle modification for patients with essential hypertension. It is generally accepted that regular aerobic exercise is effective in reducing blood pressure (BP) in this population.[3,4] However, the dose–response relations of regular aerobic exercise and BP reduction have not been determined despite the fact that such important information is critical and is even a prerequisite before any pharmacologic interventions are implemented to this high-risk population. This is unfortunate because such results would facilitate the implementation of proper exercise prescription as a lifestyle-based treatment of hypertension, and could provide critical information to primary care health providers.

One important question for those who have an interest in the area of physical activity and hypertension is how much exercise is needed to reduce BP? A currently available consensus statement for physical activity recommendation proposes that each adult should accumulate for at least 30 min of moderate physical activity most days of the week.[5] However, it is not known whether such recommended amount of exercise would be sufficient to reduce BP in hypertensive subjects. The second unresolved question is what is the optimum amount of exercise to prescribe to this population. This does not appear to be a straightforward issue because the effects of regular exer-

Table 1. Changes in selected subject characteristics in groups classified by total weekly amount of exercise

	Control (*n* = 39)	30–60 min/wk (*n* = 55)	61–90 min/wk (*n* = 54)	91–120 min/wk (*n* = 21)	>120 min/wk (*n* = 38)	Sig.
Sex (male/female)	28/11	37/18	38/16	13/8	28/10	
Exercise time (min/wk)	0.0 ± 0.0	44.7 ± 8.6	75.1 ± 8.3	103.7 ± 8.9	165.4 ± 27.5	<.001
Age (y)	49.6 ± 7.4	48.6 ± 7.7	50.3 ± 6.7	52.1 ± 6.9	51.0 ± 7.4	.30
Height (cm)	162.8 ± 8.6	162.5 ± 9.6	160.6 ± 7.3	159.8 ± 9.8	161.8 ± 8.6	.57
Body weight (kg)						
Before	69.4 ± 7.9	67.1 ± 12.0	66.3 ± 10.3	64.0 ± 10.5	64.6 ± 10.3	.20
After	68.8 ± 7.8	66.6 ± 12.2	65.7 ± 10.1*	63.4 ± 10.0	64.0 ± 9.8*	
Body mass index (kg/m^2)						
Before	26.2 ± 2.7	25.3 ± 3.0	25.6 ± 2.9	24.9 ± 2.1	24.6 ± 2.7	.13
After	26.0 ± 2.7	25.1 ± 2.9*	25.4 ± 2.8*	24.7 ± 1.8	24.4 ± 2.5*	
Total caloric intake (kcal/day)						
Before	1930 ± 520	2181 ± 611	2095 ± 409	2085 ± 625	2005 ± 581	.20
After	1977 ± 624	1971 ± 456*	1865 ± 315*	1945 ± 545	1959 ± 463	
Salt intake (g/day)						
Before	11.9 ± 3.4	11.9 ± 3.2	12.4 ± 3.2	12.8 ± 6.1	13.1 ± 3.3	.50
After	11.5 ± 3.3	11.1 ± 3.7	11.7 ± 3.2	12.6 ± 4.3	11.5 ± 3.4	

All values are means ± SD.

 * *P* < .01 *v* before; Sig. = probability of differences in baseline values among groups.

cise on arterial BP in hypertensive patients may be unique and even contrary to what we predict in terms of the dose–response issue. For example, it is generally thought that exercise training at lower, rather than higher, intensities appears to be more effective in lowering BP.[6,7] Among the three factors that characterize exercise dosage (ie, intensity, duration, and frequency), the influence of exercise frequency and duration on BP in hypertensives still remained to be elucidated. Accordingly, in the present study, we determined the dose–response relations of regular exercise and BP in essential hypertensive patients. Our hypothesis was that the greater exercise dosage would be associated with the greater reduction in arterial BP. To address this aim, we prescribed an exercise program that had a standardized exercise intensity and assessed respective influences of exercise duration and frequency on BP.

Methods
Subjects

The present study is a part of Risk Factor Intervention Trial in Japan.[8] The primary aim of this trial is to determine the influence of regular physical activity on hypertension, obesity, diabetes mellitus, and dyslipidemia. Subjects were referred and recruited from routine medical examinations at their companies or local health care centers. A total of 1425 subjects initially joined this trial. Of these, 450 subjects were identified to have stage 1 or 2 hypertension.[1] After exclusion criteria (ie, medication use, including antihypertensive drugs; presence of cardiovascular disease; recent changes in dietary habit; habitually active lifestyle) were applied, 207 otherwise healthy sub-

jects with essential hypertension were studied in the present study (Table 1). Exercise groups were divided into groups based on the weekly duration and frequency/week of exercise. None of the postmenopausal women were taking hormone replacement therapy. Small number of subjects in exercise group (<20%) were smokers. However, the smokers did not change smoking habits before and after the intervention period. In addition, the responses of smokers to exercise were not different from nonsmokers, and the exclusion of the smokers did not affect the results. None of the subjects had performed regular physical activity in the previous year. Before participation, each subject underwent physical examination and graded exercise test. All subjects gave their informed consent to participate in this study. This study was approved by the Ethics Committee of the National Institute of Health and Nutrition, Japan.

Measurements

The testing was conducted at 22 fitness clubs that have medical staff on site. To eliminate the investigator bias, arterial BP at rest was measured using an automatic oscillometric BP monitor (BP-203RVII, Colin, Aichi, Japan).[9] Arterial BP was obtained in duplicate after subjects had rested for at least 5 min in a quiet, comfortable room. The values for two recordings were averaged. Before the respective intervention period, BP was obtained on two separate visits with an interval of 2 weeks, and the average values were used as the baseline value.

Body mass was measured with the physician's balance scale. Body mass index (BMI) was calculated using the formula of body mass (in kilograms)/height (in square

meters). Dietary data were obtained from 2-day food records before and after the intervention period. Subsequently, total caloric intake and salt intake were determined from the standard tables of food composition (Science & Technology Agency of Japan). Maximal oxygen consumption (VO_{2max}) was used as a measure of maximal aerobic capacity, and was estimated on cycle ergometer as previously described by Taniguchi.[10]

Exercise Intervention

The 8-week exercise training was performed at the subjects' nearest fitness club under the supervision of personal trainers as previously described.[8] Each exercise session consisted of a brief warm-up period, aerobic exercise (eg, walking, jogging, cycle ergometer, and swimming), followed by conditioning exercises (eg, sit-ups and stretching). The exercise intensity during aerobic exercise was standardized at 50% of estimated maximal oxygen consumption, and was monitored by periodic palpation on the carotid artery or the radial artery. The type and duration of the exercise program was carefully recorded daily in the exercise log. The subjects in the nonexercising control group maintained their normal (ie, sedentary) physical activity patterns for the course of the investigation. To document this, we used the well-validated pedometers (Yamax Digiwalker, Tokyo, Japan) to estimate the level of usual physical activity in the control groups.[11]

Statistical Analyses

Test data for the groups were analyzed with ANOVA with repeated measures. In the case of a significant interaction effect, a post hoc test using Tukey's multiple comparison test was performed to identify significant differences among mean values. Analysis of covariance was also performed to analyze differences in changes of BP using baseline BP, and changes in body mass, energy, and salt intake as covariate. The probability level of statistical significance was set a priori at $P < .05$ in all comparisons. Descriptive statistics were expressed as means ± SD.

Results

Table 1 presents subject characteristics of the five groups classified by weekly duration of exercise. Before the exercise intervention, the groups were not different in relation to gender, age, height, body mass, BMI, and dietary intake ($P > .05$). Exercise training intervention significantly decreased body mass and BMI, although the magnitude of the reductions were small. No significant changes were observed in salt intake ($P > .05$).

Fig. 1 illustrates the changes in systolic BP and diastolic BP with exercise training. The changes were adjusted for baseline BP and changes in body mass, energy, and salt intake. At the beginning of the intervention, there were no significant group differences in the baseline (preintervention) BP values ($P > .05$). Both systolic and
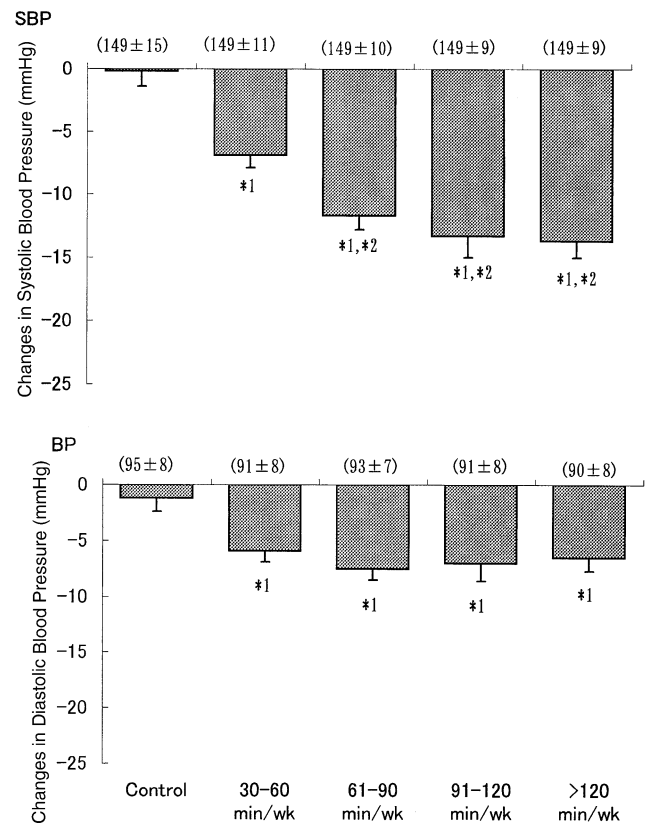
FIG. 1. Changes in resting systolic (SBP) and diastolic (DBP) blood pressure with exercise training intervention of different exercise duration. Baseline (preintervention) resting BP values are shown in parenthesis. The changes were adjusted for baseline BP, and changes in body mass and energy and salt intake. *1 < .01 v sedentary control; *2 < .01 v 30 to 60 min/wk group.

diastolic BP did not change in the nonexercising control group. All four exercise groups demonstrated significant reductions in both systolic and diastolic BP. The magnitude of reductions in systolic BP was greater in the 61 to 90 min/wk group compared with the 30 to 60 min/wk group ($P < .05$). There were no greater reductions in systolic BP with further increases in exercise volume. The magnitude of reductions in diastolic BP was not significantly different among the four exercise groups.

Fig. 2 depicts the influence of exercise frequency on the hypotensive effects of regular exercise. The changes were adjusted for baseline BP, and changes in body mass and total caloric and salt intake. There were no obvious relations between exercise frequency per week and the magnitude of BP decreases with exercise training ($P > .05$).

Discussion

The primary findings from the present study are as follows. First, even 30 to 60 min of exercise per week were sufficient to reduce both systolic and diastolic BP in patients with stage 1 or 2 essential hypertension. Second, the magnitude of reductions in systolic BP was greater in the 61 to 90 min/wk group compared with the 30 to 60 min/wk
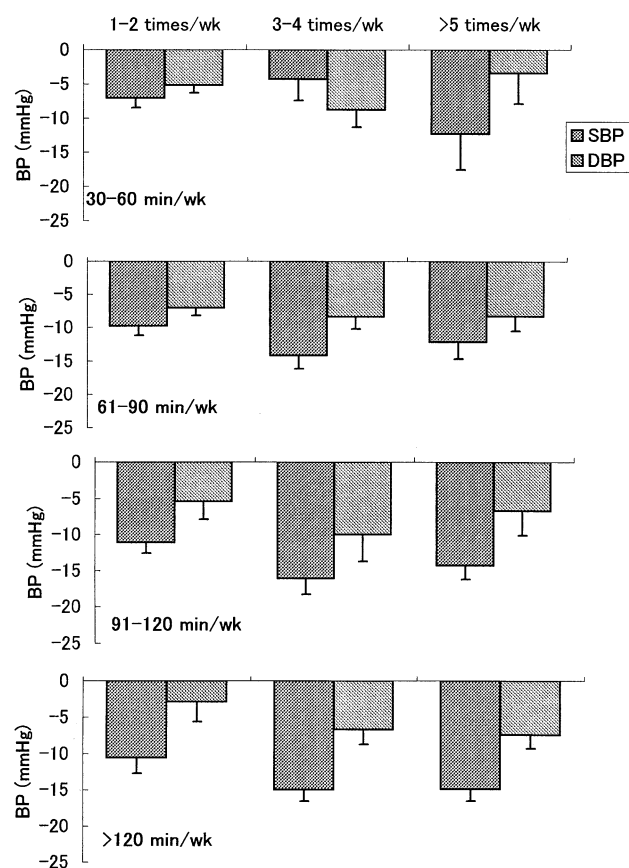
FIG. 2. Changes in resting SBP and DBP with exercise training intervention of different exercise frequency. There were no significant group differences. The changes were adjusted for baseline resting BP, and changes in body mass and total caloric and salt intake. Abbreviations as in Fig. 1.

group, but there were no greater reductions in systolic BP with further increases in exercise volume. Third, there appears to be no such dose–response relation in diastolic BP. Fourth, there was no obvious association between frequency of weekly exercise and its hypotensive effects. Our present results indicate that the amount of exercise required to reduce BP in hypertensive population may be considerably lower than the current recommendation for physical activity. More important, the volume of exercise required to reduce BP may be relatively small that should be reasonably attainable by this high-risk population.

The recent guidelines for physical activity recommended that each adult accumulate at least 30 min of moderate physical activity most days of the week.[5] Recently, an epidemiologic study challenged this recommended amount and reported that adults who exercised at least 1 h/wk had approximately half the coronary heart disease risk of those who were sedentary.[12] Our present findings are consistent with this epidemiologic study and raise the possibility that an amount of exercise that is much smaller than the recent guidelines suggest[5] may be required to reduce arterial BP in hypertensive patients. In addition, our present results may provide a mechanistic

insight into the dose–response relation between coronary disease risk and physical activity observed earlier in that epidemiologic study.[12] That is, because of the positive association between BP levels and the incidence of coronary heart disease, the reduced coronary heart disease risk even in these mild exercisers observed in the epidemiologic study[12] may be attributed, at least in part, to its effects on arterial BP as demonstrated in our present study.

To the best of our knowledge, there has been only one other intervention study to specifically address the relation between exercise amount and BP reduction in hypertensive subjects. Nelson et al[13] assessed the effects of exercise frequency on BP and found that the decrease in BP in hypertensive subjects was slightly but significantly greater on a seven times per week than three times per week exercise program. However, the reduction in BP at three times per week had already reached 70% to 100% of the response achieved with exercise seven times per week. Moreover, because total amount of exercise was 135 min/wk and 315 min/wk in three and seven times per week group, respectively, Nelson et al[13] could not isolate the effects of exercise duration from frequency. As such, it was not clear whether the difference in BP reduction could be attributed to the differences in frequency of exercise or total duration of exercise. Furthermore, no information was provided as to whether even less amount of exercise was needed to reduce BP. The present study significantly extends this previous study. Specifically, we demonstrated that weekly exercise frequency did not modulate the reduction in BP with exercise training. Rather our results indicate that exercise duration exerts more pronounced effects on BP in hypertensive subjects. Moreover, even 30 to 60 min of exercise per week were sufficient to reduce both systolic and diastolic BP in the patients with essential hypertension.

We should emphasize that our present results should not be viewed as a message against encouraging people to exercise more on a daily basis. It is important to note that depending on the cardiovascular risk factor of interest, the dose of exercise that is required to induce health benefits seems to be different. As described in the present study, the dose–response relation between exercise and BP appears to be sigmoidal, and relatively modest amount of exercise may be needed to achieve clinically significant reductions in BP. However, such amount of exercise may not be sufficient to induce changes in other risk factors including body fatness and HDL-cholesterol.[14,15]

We wish to emphasize the following major limitation of the present study. That is, the classification of the subjects into different groups was not performed randomly, and was defined after the study completion. As such, it is possible that a systematic bias may have occurred. However, the five groups were well matched for potentially confounding variables (eg, dietary sodium intake, baseline BP levels) that could affect the main conclusions of the present study. In addition, if such bias had existed, one might expect to see a systematic trend on the main results

(ie, graded reductions in BP to increased levels of exercise). However, we did not observe such a trend in the present study. Moreover, our present results are consistent with the recent epidemiologic study that adults who exercised at least 1 h/wk had approximately half the coronary heart disease risk of those who were sedentary.[12]

In summary, our present results indicate that in previously sedentary hypertensive subjects, clinically significant decreases in BP can be achieved with relatively modest increases in physical activity above sedentary levels.

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