Short-term Effect of Dynamic Exercise on Arterial Blood Pressure

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Background. To quantify the duration of postexercise hypotension at different exercise intensities, we studied six unmedicated, mildly hypertensive men matched with six normotensive controls.

Methods and Results. Each subject wore a 24-hour ambulatory blood pressure monitor at the same time of day for 13 consecutive hours on 3 different days. On each of the 3 days, subjects either cycled for 30 minutes at 40% or 70% maximum \( V_{O_2} \) or performed activities of daily living. There was no intensity effect on the postexercise reduction in blood pressure, so blood pressure data were combined for the different exercise intensities. Postexercise diastolic blood pressure and mean arterial pressure were lower by 8±1 (\( p<0.001 \)) and 7±1 mm Hg (\( p<0.05 \)), respectively, than the preexercise values for 12.7 hours in the hypertensive group. These variables were not different before and after exercise in the normotensive group. Systolic blood pressure was reduced by 5±1 mm Hg (\( p<0.05 \)) for 8.7 hours after exercise in the hypertensive group. In contrast, systolic blood pressure was 5±1 mm Hg (\( p<0.001 \)) higher for 12.7 hours after exercise in the normotensive group. When the blood pressure response on the exercise days was compared with that on the nonexercise day, systolic blood pressure (135±1 versus 145±1 mm Hg) and mean arterial pressure (100±1 versus 106±1 mm Hg) were lower (\( p<0.05 \)) on the exercise days in the hypertensive but not in the normotensive group. We found a postexercise reduction in mean arterial pressure for 12.7 hours independent of the exercise intensity in the hypertensive group. Furthermore, mean arterial pressure was lower on exercise than on nonexercise days in the hypertensive but not in the normotensive group.

Conclusion. These findings indicate that dynamic exercise may be an important adjunct in the treatment of mild hypertension. (Circulation 1991;83:1557-1561)

One in four Americans is hypertensive. Hypertension is associated with an increased incidence of stroke, heart and renal failure, myocardial infarction, and premature death. For those with hypertension, the health benefits of lowering blood pressure (BP) with medication may not outweigh the risks associated with drug treatment. Although nonpharmacological methods yield additional options for controlling hypertension, the Subcommittee on Nonpharmacological Therapy of the 1984 Joint National Committee on Detection, Evaluation and Treatment of High Blood Pressure concluded that only weight control, alcohol restriction, and sodium restriction merited scientific endorsement for incorporation into hypertension treatment programs.

Despite conflicting evidence on the antihypertensive effect of dynamic exercise on resting BP, aerobic exercise, in addition to diet modification and drug therapy, is frequently recommended by physicians and allied health professionals for the treatment of hypertension. Although the long-term influence of physical training on resting arterial BP has been widely studied, the reductions in resting arterial BP immediately after exercise have only recently begun to be quantified.

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Hannum and Kasch studied the changes in resting BP for 2 hours after 40 minutes of exercise at 64% maximum oxygen consumption (\( V_{O_2} \)) in 10 normotensive and 13 hypertensive subjects. Both groups had postexercise systolic BP (SBP) reductions compared with preexercise values, with the greater decrease seen in the hypertensive group. Hagberg et al found resting SBP to be lower in hypertensive men and women 60–69 years of age after 45 minutes of intermittent exercise at 50% and 70% maximum


**TABLE 1. Characteristics of Subjects**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hypertensive</th>
<th>Normotensive</th>
</tr>
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<tbody>
<tr>
<td>Age (yr)</td>
<td>44±4</td>
<td>41±2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174±4</td>
<td>175±2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>92.3±4.3</td>
<td>89.7±4.1</td>
</tr>
<tr>
<td>Resting MAP (mm Hg)</td>
<td>106±2*</td>
<td>91±1</td>
</tr>
<tr>
<td>$\bar{V}_o_2$ max (l/min)</td>
<td>2.6±0.2</td>
<td>2.4±0.2</td>
</tr>
</tbody>
</table>

Values are mean±SEM.
MAP, mean arterial pressure; $\bar{V}_o_2$ max, maximum oxygen consumption.

*p<0.05 hypertensive vs. normotensive.

$\bar{V}_o_2$ followed by 3 hours of recovery. The total duration of the hypotensive effect of a single session of exercise at varying intensities on resting arterial BP is unknown.

This study was designed to determine the influence of continuous, dynamic exercise of low (40% maximum $\bar{V}_o_2$) and moderate (70% maximum $\bar{V}_o_2$) intensity on postexercise hypotension in normotensive and mildly hypertensive men. In addition, we planned to quantify the duration of this effect.

**Methods**

**Subjects**

Twelve men volunteered to participate in this study. Of these men, six were classified as mildly hypertensive based on the following criteria: SBP between 140 and 160 mm Hg or diastolic BP (DBP) between 90 and 100 mm Hg. This determination was made by the examining cardiologist after reviewing 24-hour ambulatory BP measurements made on each subject with the Accutracker 103 automatic noninvasive recorder, (Suntech Medical Instruments, Inc., Raleigh, N.C.). The remaining six subjects served as the normotensive control group. Both groups were well matched on the basis of age, weight, and fitness level. The participants’ physical characteristics are shown in Table 1.

Each subject gave his informed consent and passed a physical examination to screen for medical reasons that would preclude him from undergoing strenuous exercise in an unmedicated state. Those volunteers who were taking antihypertensive medications discontinued them for at least 2 weeks before the beginning of the study. The research protocol had prior approval from the New Britain General Hospital/University of Connecticut School of Medicine Human Investigation Committee.

**Experimental Design**

Before the study, subjects were familiarized with all experimental methods and procedures. To confirm each participant’s blood pressure status, each subject wore a 24-hour ambulatory BP monitor. On the day when the monitor was worn, subjects were instructed to go about their usual activities of daily living but not to perform structured exercise. After determination of BP status, volunteers performed a graded exercise test to exhaustion on an electronically braked Mijnhardt KEM 2 cycle ergometer to determine maximal aerobic power (maximum $\bar{V}_o_2$). $\bar{V}_o_2$ was measured continuously by indirect calorimetry by a Medical Graphics 2001 metabolic cart. Heart rate (HR) was recorded from a 12-lead electrocardiogram with the Hewlett-Packard 4700 electrocardiograph (Palo Alto, Calif.). SBP and DBP were measured every other minute by auscultation. The results of this graded exercise test were used to determine the experimental exercise intensities of 40% and 70% maximum $\bar{V}_o_2$.

All experiments were conducted at the same time of day for each subject. The exercise sessions were separated by a minimum of 2 days, and all were conducted within 2 weeks. Subjects were asked to refrain from food and caffeinated beverages for 4 hours before the exercise studies. Subjects dressed in exercise clothing for each session. Before cycling, they were weighed to make certain weight remained constant during the 2-week study period. The subjects performed two 30-minute periods of cycle ergometer exercise, one at 40% and the other at 70% maximum $\bar{V}_o_2$, in a randomized crossover design.

All exercise sessions were preceded by a 10-minute control period of quiet sitting. The exercise session consisted of a 5-minute warm-up of free wheeling, followed by 30 minutes of cycling at either 40% or 70% maximum $\bar{V}_o_2$, and concluded with a 5-minute cool-down of free wheeling. Subjects then dismounted the bike and remained seated quietly for 30 minutes. HR was recorded with a TXM-205 transmitter and TEM-4000 monitor telemetry system (Transkinetics Systems, Inc., Canton, Mass.). The same observer measured SBP and DBP by auscultation. DBP was recorded at the disappearance of the fourth Korotkoff sound. SBP and DBP were used to calculate mean arterial pressure (MAP) according to the formula: (2DBP+SBP)/3.

HR, SBP, and DBP were recorded every minute of the 10-minute control period, every minute of the 5-minute warm-up, every 5 minutes of the 30-minute exercise period, and every minute of the 5-minute cool-down. During the 30-minute recovery period of quiet sitting, HR, SBP, and DBP were taken every minute for the first 10 minutes and every 3 minutes thereafter.

At the beginning of the recovery period of quiet sitting, the Accutracker blood pressure monitor was attached to each subject by positioning the sound transducer over the brachial artery. The monitor was adjusted until two successive measurements agreed to within 5 mm Hg of auscultatory values taken manually. It was programmed to record SBP, DBP, and HR every 30 minutes. At the conclusion of the recovery period, subjects were instructed to proceed with their usual activities of daily living, and they then left the laboratory.

The same observer edited all ambulatory monitor readings and excluded all measurements meeting the following criteria: DBP less than 50 or greater than 130 mm Hg, SBP less than 70 or greater than 250
mm Hg, SBP less than DBP, or HR less than 40 or greater than 200 beats/min.

**Statistical Analyses**

Data were analyzed for differences between groups, exercise intensity, and over time with a repeated measures analysis of variance. Exercise intensity did not affect the BP response; therefore, all exercise data were combined in the statistical analyses. If significant effects for blood pressure status were found, the mean BP values for each group were tested with the Student’s paired t test to determine at which times, that is, before versus after exercise, the values were different. Last, BP readings were averaged over the two exercise days and the nonexercise day for the hypertensive and normotensive groups. These means were tested for differences with the independent samples t test.

**Results**

Postexercise BP was significantly lower than preexercise for the hypertensive group. The mean values before and after exercise for the hypertensive and normotensive groups are shown in Table 2. In the hypertensive group, SBP was reduced from 136±2 before to 130±1 mm Hg for 8.7 hours after exercise (p<0.05). DBP was 9±1 mm Hg (p<0.001) and MAP was 8±1 mm Hg (p<0.05) lower for 12.7 hours after exercise compared with values before exercise. The BP response of the hypertensive group before, during, and after exercise is shown in Figure 1.

In contrast to the hypertensive group, the normotensive group’s DBP (76±1 versus 74±1 mm Hg) and MAP (90±1 versus 90±1 mm Hg) were not different before and after exercise, respectively (Table 2). Furthermore, the normotensive group’s SBP was 5±1 mm Hg higher (p<0.001) for 12.7 hours after exercise than during the preexercise control period. The normotensive group’s BP response before, during, and after exercise is shown in Figure 2. HR was not different before and after exercise for the hypertensive (83±4 versus 80±1 beats/min) and normotensive groups (69±2 versus 78±1 beats/min).

Table 3 compares the BP response of both groups averaged over the nonexercise control day and the two exercise days. Mean SBP was significantly lower on the exercise than on the non-exercise days in the hypertensive group (135±1 versus 145±1 mm Hg) (p<0.001) but not in the normotensive group (125±1 versus 127±1 mm Hg), respectively. Similarly, DBP and MAP were reduced 4±1 and 5±1 mm Hg, respectively, on the exercise compared with the nonexercise day in the hypertensive group. However, no differences in SBP, DBP, and MAP were noted on these days in the normotensive group.

**Discussion**

In hypertensive men, arterial blood pressure was lower for 12.7 hours after exercise at 40% and 70% maximum VO$_2$ than that before exercise. Our findings are consistent with earlier reports of postexercise hypotension in hypertensive subjects for up to 4 hours after exercise.$^{13-17}$ Furthermore, the use of the ambulatory BP monitor enabled us to observe the hypotensive effects of a short-term session of exercise for a greater time frame after exercise (13 hours) than have previous studies.

The effect of dynamic exercise on recovery BP in normotensive subjects is less clear. In our study, MAP after exercise was similar to resting values in the normotensive group. Other investigators have found postexercise BP to be similar to or lower than

table 2. average preexercise and postexercise cardiovascular data by blood pressure status for up to 12.7 hours after exercise

<table>
<thead>
<tr>
<th></th>
<th>Hypertensive</th>
<th>Normotensive</th>
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<tbody>
<tr>
<td></td>
<td>Exercise</td>
<td>Exercise</td>
</tr>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>136±2</td>
<td>130±1*</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>91±2</td>
<td>82±1†</td>
</tr>
<tr>
<td>MAP (mm Hg)</td>
<td>106±1</td>
<td>98±1‡</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>83±4</td>
<td>80±1</td>
</tr>
</tbody>
</table>

Values are mean±SEM. SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; HR, heart rate.

*p<0.05 before vs. after exercise for 8.7 hours; †p<0.01 before vs. after exercise; ‡p<0.05 before vs. after exercise.
BP measured before exercise.\textsuperscript{15,16,18} A possible explanation for the different BP responses after exercise reported in normotensive subjects is that the absolute changes in recovery BP are less than those in hypertensive subjects and, thus, less likely to reach statistical significance.\textsuperscript{11,12}

Not only was postexercise BP lower than resting BP in the hypertensive group in our study, but MAP averaged 6 mm Hg lower on the exercise days than on the control (nonexercise) day. In contrast, MAP was not different on any of these days in the normotensive group. All previous studies that have reported postexercise hypotension in hypertensive subjects measured recovery BP in the controlled setting of the laboratory.\textsuperscript{14–17} However, we asked our volunteers to go about their usual activities of daily living, including work while their postexercise BP was being recorded with the ambulatory monitor. Because the conditions under which BP were measured in our study have the potential to be more stressful than the quiet rest of the laboratory, the hypotensive influence of a short-term session of steady-state exercise may be more significant than previously thought. Furthermore, previous investigations\textsuperscript{19,20} have shown that average daily ambulatory BP readings may yield more accurate characterizations of an individual's BP status than either clinic or home measurements.

We found that an exercise intensity of 40% maximum \( \dot{V}_O_2 \) elicited a mean postexercise SBP-lowering effect of the same magnitude as 70% maximum \( \dot{V}_O_2 \), 6 versus 5 mm Hg, respectively, for 12.7 hours in mildly hypertensive men. In addition, low-intensity exercise decreased SBP as effectively as moderate intensity exercise, 11 versus 9 mm Hg, respectively, on the exercise compared with nonexercise days in mildly hypertensive men. Similarly, Hagberg et al\textsuperscript{14} reported SBP to be lower in older hypertensive men for up to 3 hours after three 15-minute sessions of treadmill exercise conducted at 50% and 70% maximum \( \dot{V}_O_2 \). Although the minimum amount of exercise needed to accrue health benefits such as decreased BP has yet to be defined,\textsuperscript{21,22} low-intensity exercise (40–50% maximum \( \dot{V}_O_2 \)) appears to be as effective as moderate-intensity exercise (70% maximum \( \dot{V}_O_2 \)) in reducing BP for the 7 hours after exercise in mildly hypertensive men.

The hypertensive effect of physical training remains controversial in hypertensive men.\textsuperscript{5–12} However, a short-term session of aerobic exercise conducted at low-to-moderate intensities reduces BP for up to 13 hours after exercise in hypertensive subjects compared with preexercise BP. Furthermore, on days when mildly hypertensive men exercise, their BP is lower than on days when they do not. These reductions in BP associated with exercise may be of sufficient magnitude to normalize the BP of certain mildly hypertensive men. Most adults are comfortable exercising within the intensity range used in this study, which resembles leisurely to brisk walking.\textsuperscript{21,22} From a public health viewpoint, low-to-moderate aerobic activity may be an important adjunct in the treatment of mild hypertension, merely based on its short-term effect of lowering postexercise BP.

**Acknowledgment**

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**References**

3. Subcommittee on Nonpharmacological Therapy: Nonpharmacological approaches to the control of high blood pressure:

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