ABNORMAL RESPONSE OF BLOOD PRESSURE TO MASTER’S TWO-STEP EXERCISE IN PATIENTS WITH ESSENTIAL HYPERTENSION

KYUZO AOKI, M.D., SETSUKO KATO, M.D., AKIHIRO MOCHIZUKI, M.D.
YOSHINORI KAWAGUCHI, M.D., AND MASAHIKO YAMAMOTO, M.D.

To clarify the differences in response of blood pressure (BP) in the normotensives and the hypertensives (n = 30, 40 ± 9 years, 142 ± 17 / 91 ± 14 mmHg, mean ± SD), the subjects were divided into normotensives (N) (n = 13, 34 ± 5 years, 114 ± 6 / 72 ± 8 mmHg), prehypertensives (n = 8, 38 ± 11 years, 125 ± 6 / 80 ± 3 mmHg), borderlines (n = 13, 38 ± 10 years, 140 ± 12 / 85 ± 9 mmHg), and established hypertensives (n = 9, 43 ± 6 years, 161 ± 9 / 108 ± 8 mmHg).

BP and heart rate were measured in the supine position after a 30-min bed rest and the recovery phase following the double Master’s two-step exercise. The rise in systolic BP was significantly greater in the prehypertensives and in the borderlines than in N, but was insignificantly smaller in the established. The rise in diastolic BP was significantly greater in all the groups of the hypertensives than in N. This rise was significantly greater in the borderlines than in the established. A multiple regression correlated significantly between the rise in BP and the resting BP (r = 0.467 in systolic, and r = 0.373 in diastolic). Diastolic BP following exercise increased in the hypertensives, but fell in N. The rise in heart rate was not significantly different between the hypertensives and N. The hyperresponse observed in both prehypertensives and the borderlines was diminished in the established hypertensives.

These results suggest that the hyperresponse of BP may play an important role in the development of hypertension in the patients with essential hypertension.

It is still uncertain whether or not blood pressure (BP) responses to stimuli are greater in subjects with essential hypertension than in subjects with normotension. In the previous studies of BP response in subjects with normotension and hypertension, the results were extremely varied. They included a great rise of diastolic BP to orthostatic stress in subjects with borderline hypertension, a great systolic response to mental and other stresses in subjects with hypertension and their offspring, and the equal response of BP to stimuli in subjects with hypertension and normotension. The rise in systolic BP following exercise in the normotensives did not differ from the young subjects with hypertension and

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The Second Department of Medicine, Nagoya City University Medical School, Nagoya, Japan
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Address for correspondence: KYUZO AOKI, M.D., The Second Department of Medicine, Nagoya City University Medical School, Mizuho-ku, Nagoya 467, Japan

Japanese Circulation Journal Vol. 46, March 1982 261
<table>
<thead>
<tr>
<th>No. of cases</th>
<th>Sex (M/F)</th>
<th>Age (years)</th>
<th>Cardio-thoracic ratio in X-ray (%)</th>
<th>Electrocardiogram</th>
<th>Ccr (ml/min)</th>
<th>Plasma renin activity (%)</th>
<th>Ocular fundi (Scheie)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normotension</td>
<td>13/0</td>
<td>33.9</td>
<td>48.0</td>
<td>3.0 ±0.5</td>
<td>108 ±13</td>
<td>32 ±4</td>
<td>0.1-1</td>
</tr>
<tr>
<td>Hypertension</td>
<td>24/6</td>
<td>39.7</td>
<td>49.7</td>
<td>3.7 ±1.0</td>
<td>105 ±11</td>
<td>30 ±5</td>
<td>0.1-1</td>
</tr>
<tr>
<td>Group H-1</td>
<td>6/2</td>
<td>37.6</td>
<td>49.8</td>
<td>3.9 ±1.0</td>
<td>104 ±11</td>
<td>31 ±5</td>
<td>0.1-1</td>
</tr>
<tr>
<td>Group H-2</td>
<td>11/2</td>
<td>37.9</td>
<td>48.7</td>
<td>3.6 ±0.5</td>
<td>108 ±11</td>
<td>31 ±5</td>
<td>0.1-1</td>
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<tr>
<td>Group H-3</td>
<td>7/2</td>
<td>43.0</td>
<td>50.7</td>
<td>4.3 ±1.1</td>
<td>98 ±15</td>
<td>30 ±5</td>
<td>0.1-1</td>
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| H-1 vs H-2  |           |             |                                   |                 |             |                          |                      |
| H-1 vs H-3  |           |             |                                   |                 |             |                          |                      |
| H-2 vs H-3  |           |             |                                   |                 |             |                          |                      |

M = male, F = female, Ccr = creatinine clearance test, PSP = phenolsulphonphthalein excretion, ns = no significance

Those who classified as WHO Stage 1 but a great rise in the systolic BP was recorded in the old subjects with hypertension and those who as WHO Stages 2 and 3 has demonstrated that the rise in diastolic and systolic BP to dynamic exercise was smaller in young subjects with hypertension than in subjects with normotension. Our previous study demonstrated that the rise in BP due to handgrip exercise was smaller in the prehypertensive stage of hypertension but greater in subjects with borderline and established hypertension than in subjects with normotension. The discrepancies in these results may be explained by the fact that all subjects belonged to the various stages of hypertension and that various methods were used for measuring BP.

In the present study, we attempted to clarify the existence of differences in response to exercise in subjects with normotension and with various stages of essential hypertension. From this point of view, subjects with hypertension were divided into the prehypertensive, the borderline and the established stages of essential hypertension, according to the BP after a 30-min supine bed rest in the comfortable exercise room. To exclude the response due to anxiety, we used such simple accustomed noninvasive methods as Master's two-step exercise and auscultatory measurement of BP. For our precise measurement, BP and heart rate (HR) were taken in the supine bed rest position before and after exercise. The BP responses to exercise in the normotensives were compared with that in the various stages of essential hypertension to discover whether or not the hypertensives had an abnormal BP response following the two-step exercise.

SUBJECTS

Thirteen healthy volunteers with normotension (BP < 140/90 mmHg) were selected, all having negative family histories and no episodes of hypertension. Thirty subjects with essential hypertension were selected on the basis of both a positive family history of hypertension and high BP, that is, high casual BP of 140 mmHg or higher in systole and/or 90 mmHg or higher in diastole at least on 3 separate days during the observation.
Abnormal Response of Blood Pressure in Hypertension

(HR) TO DOUBLE MASTER'S TWO-STEP EXERCISE IN SUBJECTS WITH NORMOTENSION AND

<table>
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<th>BP mmHg</th>
<th>HR beats/min</th>
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<tr>
<td></td>
<td>After a 5-min supine bed rest in the clinic room</td>
</tr>
<tr>
<td>SBP</td>
<td>115.0 ± 8.0</td>
</tr>
<tr>
<td>DBP</td>
<td>74.0 ± 7.0</td>
</tr>
<tr>
<td>SBP</td>
<td>158.3 ± 15.0***</td>
</tr>
<tr>
<td>DBP</td>
<td>104.5 ± 8.0***</td>
</tr>
<tr>
<td>SBP</td>
<td>150.0 ± 12.0***</td>
</tr>
<tr>
<td>DBP</td>
<td>97.3 ± 7.4***</td>
</tr>
<tr>
<td>SBP</td>
<td>158.0 ± 17.2***</td>
</tr>
<tr>
<td>DBP</td>
<td>103.0 ± 6.0***</td>
</tr>
<tr>
<td>SBP</td>
<td>167.0 ± 17.0***</td>
</tr>
<tr>
<td>DBP</td>
<td>113.3 ± 6.4***</td>
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SBP/DBP ns/ns ***/ns ns/ns ns/ns ns ns ns

SBP/DBP * / * **** / *** ns/ *** **/ns ns ns ns

SBP/DBP * / * **** / *** ns/ *** ***/ ns ns ns

SBP = systolic BP, DBP = diastolic BP. Values = mean ± SD. * p < 0.05, ** p < 0.01, *** p < 0.001.

period of 3 months. In the normotensives and hypertensives, 3 measurements of BP and HR were obtained after a 5-min supine bed rest position in the clinic room in the morning. In all subjects urine analysis, determination of blood urea nitrogen, examination of serum (creatinine, glucose, sodium, potassium, chloride, bicarbonate, calcium and protein), and intravenous pyelogram were within normal limits. All the hypertensives were in the WHO hypertension Stage of 1 or 2.

METHODS

After a 4-week discontinuation of all medications, all the subjects were instructed to take a 30-min supine bed rest in a quiet and comfortable exercise room in the morning, then BP and HR were measured several times to demonstrate their stability. These measurements were regarded as the resting BP and the resting HR. After that the 3-min double Master's two-step exercise was performed, and then supine bed rest was immediately instructed, and BP and HR were measured at 30 sec, 1, 3, 5 and 10 min following exercise (recovery phase).

BP was measured by auscultation on the right arm with a mercury manometer. Diastolic BP was taken at the point where some sounds disappeared (Korotkoff phase V) or, when they did not disappear so distinctly, at the level in which they become abruptly muffled (phase IV). HR was measured electrocardiographically with a monitor. Two weeks after exercise, venous blood was obtained after a 2-hour supine bed rest in the morning. Resting plasma renin activity was measured by radioimmunoassay.

The subjects with hypertension were divided into 3 subgroups according to the resting BP:

- Group H-1 (the prehypertensive stage), BP < 140/90 mmHg,
- Group H-2 (the borderline stage), systolic BP of 140–159 mmHg and/or diastolic BP of 90–99 mmHg, and
- Group H-3 (the established stage), systolic BP of 160 mmHg or higher and/or diastolic BP of 100 mmHg or higher.

Data were expressed as mean ± SD, and analysed statistically by Student's paired t-test.
Multiple regression and the correlative coefficients were calculated. P values of 0.05 or less were considered significant.

RESULTS

Systolic Blood Pressure

The resting BP was significantly higher in the hypertensives than in the normotensives. BP 30 sec after exercise was significantly higher than the resting BP in all the groups. The rise in BP 30 sec after exercise was significantly greater in Groups H-1 and H-2 than that in the normotensives, but was insignificantly smaller in Group H-3 than in the normotensives (Table I and Fig. 1). The rise in BP was significantly correlated with the resting BP by multiple regression analysis (\( Y = -2.278 \times 10^{-2} X^2 + 6.16X - 378.1, r = 0.467, p < 0.01, n = 43 \)). The rise increased to 39.6 mmHg with an increase in the resting BP to 135 mmHg, and then decreased with an increase in the resting BP above 135 mmHg (Fig. 2).

Systolic BP 3 min after exercise did not differ from the resting BP in Group H-1 and the normotensives, but remained significantly higher in Groups H-2 and H-3, i.e., the return of BP to the resting level was delayed in Groups H-2 and H-3 as compared with the normotensives. BP 10 min after exercise was the same as the resting one in all the groups.

Diastolic Blood Pressure

The resting BP was significantly higher in the hypertensives than in the normotensives. BP 30 sec after exercise was significantly higher than the resting BP in the hypertensives. In the contrary, BP 30 sec after exercise was significantly lower than the resting BP in the normotensives.

Fig. 1. The rise in systolic blood pressure (SBP) (left column) and diastolic blood pressure (DBP) (right column) from the resting BP 30 sec after Master's two-step exercise. Normotension (○), Group H-1 (●), Group H-2 (▲), and Group H-3 (■). Statistical significance of rise in Groups H-1, H-2 and H-3 to the rise in the normotensive group: ** p < 0.01, *** p < 0.001.

Fig. 2. The multiple regression and significant correlation between the rise (change) in systolic blood pressure (SBP) and the resting SBP. Normotension (○), Group H-1 (●), Group H-2 (▲) and Group H-3 (■).

Fig. 3. The multiple regression and significant correlation between the rise (change) in diastolic blood pressure (DBP) and the resting DBP. Normotension (○), Group H-1 (●), Group H-2 (▲) and Group H-3 (■).
The rise was significantly greater in Groups H-1, H-2 and H-3 than in the normotensives. This rise was significantly greater in Group H-2 than in Group H-3 (Table I and Fig. 1). The rise in BP was significantly correlated with resting BP by multiple regression analysis \( Y = -9.25 \times 10^{-2}X^2 + 1.741X - 76.8, \ r = 0.373, \ p < 0.05, \ n = 43 \). The rise increased to 5.1 mmHg with an increase in the resting BP to 94 mmHg, and then decreased along with an increase in the resting BP (Fig. 3).

Diastolic BP 30 sec after exercise was significantly higher than the resting BP in the hypertensives. BP one min after exercise was equal to the resting BP in the normotensives, but was significantly higher than the resting BP in the hypertensives. The return of BP to the resting level was delayed in the hypertensives.

**Heart Rate**

The resting HR was insignificantly greater in Group H-1 than in the other groups. The rise in HR 30 sec after exercise was not significantly different from the normotensives and the hypertensives. The return of HR to the resting level was slightly delayed in Groups H-1 and H-2.

**DISCUSSION**

Our data demonstrated a great rise in systolic and diastolic BP as a response to the Master's two-step exercise in the pre-hypertensive and borderline stages of essential hypertension, and conversely a small rise in systolic BP in the established stage. A great response of BP to stress has been found in the borderline hypertensives and genetic early-stage and labile hypertension when noninvasive methods were used. Invasive methods showed, however, that the BP response to dynamic exercise in the young subjects with early-stage or borderline-stage of hypertension was the same as or smaller than in the normotensives. Although the standard noninvasive auscultatory method to it, arterial catheterization induced a rise in BP modifying the cardiovascular response to a significant degree. BP in the subjects with labile or borderline hypertension probably had already risen during the invasive catheterization before exercise due to their hyperresponse of BP to pressor stimuli. Exercise following catheterization may then give only a small additional rise in BP in the hypertensives.

The significant, multiple, and regressive correlation between the rise in BP and the resting BP suggests that there are at least 2 factors, and may be some multiple factors that determine the magnitude of the response to the stimuli. Therefore, the hyperresponse in the prehypertensives and the borderlines and the hyporesponse in the established hypertensives may be induced by the multiple factors, such as the nature of vascular smooth muscle, connective tissue in the vascular wall, vasoactive humoral factors and many other factors which affect the BP. It may be speculated that the greater sensitivity in the intrinsic factors of arterial smooth muscle to contraction in essential hypertension may be a responsible factor for the hyperresponse in essential hypertension. The hyperresponse of BP may play an important role in the development of hypertension in the patients with essential hypertension. In this study, the reasons for the abnormal response in the hypertensives are still uncertain.

Our data demonstrated an increase in supine diastolic BP after the two-step exercise in the hypertensives, and conversely a fall in BP in the normotensives. Wolthus et al and Bruce et al reported that the supine BP fell at recovery phase after treadmill exercise in the normotensives. These results suggested that a mechanism of fall of diastolic BP after dynamic exercise operated in the normotensives, but did not operate in the hypertensives. An abnormal increase in diastolic BP may be concerned in a defect or hypofunction of arteriolar vasodilation following dynamic exercise, which may consist of myogenic mechanism in the vascular smooth muscle, and metabolic and nervous mechanisms to regulate BP in subjects with essential hypertension. It may be speculated that a defective relaxing activity of the arterial smooth muscle may be a responsible factor for the abnormal increase in diastolic BP following dynamic exercise in subjects with essential hypertension.

For the evaluation of the response of BP, the stimulation should be the equal work load for each subject. Oxygen requirements per kilogram of body weight is one of the indicator of the grade of the stimulation, which were very high for the lighter subjects and much less for the heavier subjects in the double Master’s exercise. In this study, both the lightest and the heaviest subjects were excluded in each group. The weight and the ratio of height/weight used were not significantly different between each group (body weight 63 ± 7, 62 ± 7, 64 ± 7 and 64 ± 7 kg; the ratio = 2.5 ± 0.2, 2.6 ± 0.3, 2.7 ± 0.3, and
2.6 ± 0.3 cm/kg, in the normotensives, Group H-1, H-2 and H-3, respectively). Therefore, the double Master’s exercise was approximately equal in stimulation for each subject in this study.

Any significant difference between the normotensives and the hypertensives was not observed in resting HR and HR after exercise. It has been reported that there is no difference in HR between the normotensives and the hypertensives at rest and on exercise using noninvasive methods whereas a faster HR was found in the hypertensives using invasive methods. Invasive methods of the intravascular catheters changed cardiovascular response. Those methods might induce a noticeable increase in HR in the hypertensives.

The baseline state was probably important to evaluate the response of both BP and HR in the normotensives and the hypertensives, because very minor stimuli might markedly increase BP and HR during the baseline state in the prehypertensive and borderline stages of essential hypertension.

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