Prolonged Isometric Exercise

Part 2: Effect on Circulation and on Renal Excretion of Sodium and Potassium in Young Males Genetically Predisposed to Hypertension

PATRICK S. PARFREY, B.SC, M.R.C.P., PATRICIA WRIGHT, S.R.N., N.D.N.CERT., DIP.H.V.,
AND JOHN M. LEDINGHAM, M.D., F.R.C.P.

SUMMARY The effect of stress, in the form of prolonged isometric exercise, on the circulation and on the renal excretion of sodium and potassium was studied in 16 male medical students whose parental blood pressure (BP) was less than 140/85 mm Hg, and in 17 male students with one or two parents who had BPs greater than 150/95 mm Hg. After the subjects rested initially for 90 minutes, basal measurements were made of heart rate, BP, and the rates of sodium and potassium excretion. The subjects then underwent a 1-hour period of intermittent isometric exercise involving all four limbs in rotation, during which BP and heart rate were measured. A 5-hour period of rest followed, during which BP, heart rate, and the rate of electrolyte excretion were measured at half-hourly intervals for the first 2 hours and at hourly intervals for the last 3 hours. The precise protocol was repeated on another day in the absence of the period of isometric exercise. The electrolyte excretion responses of each subject were then expressed as the ratio of the changes from basal values observed on exercise and rest days. At no time was there any difference in systolic and diastolic BP, heart rate, and rate of sodium and potassium excretion following exercise when sons of normotensive parents were compared to the sons of hypertensive parent(s). These results indicate that the retention of sodium and potassium following isometric exercise seen in patients with hypertension does not occur in subjects genetically predisposed to hypertension and suggest that the effect is a consequence of, rather than a predisposing factor to, hypertension. (Hypertension 3: 188-191, 1981)

KEY WORDS • exercise stress • blood pressure • renal sodium excretion • renal potassium excretion • genetic risk • essential hypertension

EVER since Morgagni described the familial occurrence of apoplexy, the relative contribution of genetic and environmental factors to the etiology of essential hypertension has been disputed. As far back as 1934, Ayman, in a study of 1524 members of 277 families, identified a major genetic contribution to arterial pressure, when he discovered that the prevalence of hypertension (140/80 mm Hg or higher) in offspring aged 14-39 years was 46% if both parents were hypertensive, 28% if one parent was hypertensive, and only 3% if neither parent was hypertensive. Further studies of monozygotic and dizygotic twins, spouse pairs, genetically related members of the same family, and adopted children confirmed an undoubted genetic contribution to the height of blood pressure (BP). The abnormalities that lead to clinical manifestations of sustained hypertension must occur long before the disease manifests itself. A study of the normoten- sive children of hypertensive parents may therefore reveal abnormalities relevant to the pathogenesis of hypertension.

In Part 1 of this study, we reported that patients with mild hypertension were found to differ from normal subjects in that they did not show an increase in sodium and potassium excretion following isometric exercise. As this response may be the result of, rather than an underlying cause of, hypertension, a similar experiment was performed on young male subjects genetically predisposed to hypertension, to discover whether they had an abnormal pressor response to exercise stress and whether abnormal retention of sodium and potassium occurred following prolonged isometric exercise.

Methods

Thirty-three white, male medical students (aged 19-22 years) and their parents were studied. Supine parental BP was measured by the family doctor using cuff sphygmomanometry, phases I and V, on three oc-
TABLE 1. Increase in Blood Pressure and Heart Rate (Mean ± SE) During and Immediately After Isometric Exercise in the Sons of Normotensive (PNT) and Hypertensive (PHT) Parents

<table>
<thead>
<tr>
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<th>Increase during exercise</th>
<th></th>
<th>Increase after exercise</th>
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<tbody>
<tr>
<td></td>
<td>PNT</td>
<td>PHT</td>
<td>sig of diff</td>
<td>PNT</td>
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<tr>
<td>Δ Systolic BP</td>
<td>19.6 ± 2.0</td>
<td>23.9 ± 4.0</td>
<td>ns</td>
<td>16.9 ± 3.2</td>
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<td>(mm Hg)</td>
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</tr>
<tr>
<td>Δ Diastolic BP</td>
<td>15.1 ± 3.1</td>
<td>16.6 ± 1.6</td>
<td>ns</td>
<td>3.7 ± 2.4</td>
</tr>
<tr>
<td>(mm Hg)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Δ Heart rate</td>
<td>22.3 ± 2.8</td>
<td>24.9 ± 3.0</td>
<td>ns</td>
<td>6.3 ± 2.9</td>
</tr>
<tr>
<td>(beats/min)</td>
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The changes are calculated from the mean of the four basal measurements preceding exercise and the mean of the seven measurements made during and immediately after each phase of leg isometric exercise.

The protocol of the experiment, BP measurement, and statistical analysis were exactly as described in Part 1. After the subjects underwent an initial resting period of 90 minutes, basal measurements of heart rate, BP, and of the rates of sodium and potassium excretion were made. A 1-hour period of intermittent isometric exercise involving all four limbs in rotation ensued, during which BP and heart rate were measured. A 5-hour period of rest followed, during which observations on BP, heart rate, and electrolyte excretion were made at half-hourly intervals for the first 2 hours and at hourly intervals for the last 3 hours. The precise protocol was repeated on another day in the absence of the period of isometric exercise. The electrolyte responses of each subject were then expressed as the ratio of the changes from basal values observed on exercise and rest days.

Results

Basal Values

Mean basal systolic and diastolic BPs, using results from both days, were significantly higher in PHT compared to PNT. In PHT, systolic BP was 119 ± 2.7 mm Hg and diastolic BP was 74.4 ± 2.1 mm Hg, compared to 113 ± 2.0 and 72.6 ± 2.1 mm Hg, respectively, in PNT. The mean heart rate was 72 ± 2.0 beats/min in PHT and 70 ± 2.1 beats/min in PNT.

FIGURE 1. Mean ± SE sodium excretion rate (mmole/hr) during rest and exercise days in the sons of normotensive parents and the sons of hypertensive parent(s).
Cardiovascular Response During and After Exercise

During leg isometric exercise, systolic BP increased on average by 22 mm Hg, diastolic BP by 16 mm Hg, and heart rate by 24/min (table 1). There were no significant differences between PHT and PNT. Immediately after exercise, BP and PR fell toward baseline, the changes being similar in both groups. No adaptation of the circulatory responses to isometric exercise during the seven exercise cycles occurred in either group. The circulatory changes for the first 5 hours following exercise were similar in both PHT and PNT, with no difference observed in the changes from basal rates on exercise and rest days.

Electrolyte Excretory Responses to Exercise

Figure 1 illustrates the sodium excretion rates on rest and exercise days for PHT and PNT; it can be seen that the pattern of excretion was similar in both

![Graph](image)

**Figure 2.** Mean ± SE sodium excretion response, expressed as the ratio of changes from basal on rest and exercise days, to prolonged isometric exercise in the sons of normotensive parents (PNT) and the sons of hypertensive parent(s) (PHT)

**Figure 3.** Mean ± SE potassium excretion rate (mmole/hr) on rest and exercise days in the sons of normotensive parents and the sons of hypertensive parent(s)
EXERCISE STRESS, HEREDITY AND ELECTROLYTE EXCRETION IN HYPERTENSION/Parfrey et al 191

The sodium excretion response to exercise compared to the rest day was a mean increase significant for the first hour after exercise, when both groups were combined, without any significant difference in response between the two groups being demonstrated at any stage (fig. 2).

Figure 3 illustrates the K excretion rate on rest and exercise days for PHT and PNT. Again the pattern of excretion on both days was similar in both groups. The K excretion response to exercise, compared to the rest day, was the same in both groups (fig. 4).

There was no relationship between the electrolyte excretion response to exercise and the pressor response during exercise, or the basal BP, in either PHT or PNT.

Discussion

The results of the present study show that the circulatory response during isometric exercise in normal young men is similar to that found in older adults (Part I). A similar observation was made by Laird et al.

In this investigation it was also observed that the circulatory response to isometric exercise, both in magnitude and duration, was similar in the sons of hypertensive and normotensive parents. It is of interest that when a mental stress was applied, instead of an exercise stress, Falkner et al. demonstrated that the response of some of their normotensive subjects who were genetically predisposed to hypertension was qualitatively similar to the group with labile hypertension and significantly different from that of the controls in diastolic pressure and heart rate, both during 10 minutes of mental stress and on cessation of stress. They arbitrarily separated a group of subjects predisposed to hypertension, with high response to stress, and suggested that these subjects may have increased sympathetic activity, mediated through the central nervous system. We could not define a similar subgroup using isometric exercise as the test stimulus.

The effect of static exercise on the renal excretion of Na and K was similar in sons of hypertensive and normotensive parents, the trend of the response, but not the magnitude, being the same as in older normal subjects (Part I). This may be related to the observation that the response of noradrenaline, and BP, to stress increases with age. The normal group in Part I is not strictly comparable to the PNT group because the former group is older and consists of individuals diverse for race and color. Nevertheless, there was predominant natriuresis on the exercise day relative to the rest day in both PNT and PHT, which was significant for the first hour after exercise.

The abnormality of electrolyte excretion discovered in patients with mild hypertension (Part I) was not present in patients genetically predisposed to hypertension. In patients with mild hypertension, the protracted sodium and potassium retention after isometric exercise could have been due either to excessive renal sympathetic nerve activity or to an abnormally large and prolonged response of the kidney to the normal sympathetic activity associated with exercise due to some change in the kidney resulting from high BP. However, in the light of the experiments reported here, in male subjects genetically predisposed to hypertension, neither of these postulated causes is likely to be an initiating factor in the genesis of hypertension.

References

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P S Parfrey, P Wright and J M Ledingham

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