Interaction of Sodium Sensitivity and Stress in Young Adults

Bonita Falkner and Harvey Kushner

The interaction of sodium sensitivity and stress-induced cardiovascular reactivity was studied in white and black young adults aged 18–23 years. The cardiovascular response to difficult mental arithmetic was measured before and after 14 days of oral sodium loading (10 g NaCl/day added to the usual diet). A sodium-sensitive blood pressure response occurred in 18.4% of whites and 37.3% of blacks. A significant correlation between blood pressure change and sodium excretion occurred in the sodium-sensitive group (r = −0.28, p < 0.01). High sodium intake did not augment blood pressure or heart rate response to the β-adrenergic-mediated stimulus of mental arithmetic in the population, which was grouped by blood pressure, race, or sodium sensitivity. (Hypertension 1991;17[suppl I]:I-162–I-165)

Epidemiological studies have demonstrated an ecological association of environmental stressors with higher average blood pressure and greater hypertension-related mortality.1 Because of these reports and several experimental studies, it has been proposed that an excessive cardiovascular response to physical or mental stressors may contribute to the development of essential hypertension.2 However, the relation of stress-induced cardiovascular reactivity to the pathogenesis of essential hypertension has not been determined.

There are also considerable epidemiological data that implicate dietary sodium as an etiological factor in the development of essential hypertension.3 Although sodium intake correlates with the prevalence of hypertension among populations, the effect of sodium intake among individuals is less consistent. In extensive studies on sodium sensitivity, Weinberger et al4 have found racial variation in blood pressure responses to sodium loading and sodium depletion, with a greater prevalence of sodium sensitivity among blacks.

The purpose of our study was to determine the possible existence of an interaction of stress-induced blood pressure response and sodium sensitivity. The study was designed to compare these parameters in young adult blacks and whites.

Methods

Participants in this project were all healthy young adults aged 18–23 years who had participated in longitudinal studies throughout adolescence. The study was approved by the Institutional Review Board of Hahnemann University. Written informed consent was obtained from all participants at the time of enrollment. Before enrollment, all subjects had blood pressure measurements taken. Subjects with diastolic blood pressure greater than 95 mm Hg and those on antihypertensive therapy were excluded. The average seated blood pressure obtained on the day of preloading laboratory assessment was used as the preintervention casual blood pressure for this study.

The stress-testing protocol was similar to that previously described.5 Subjects rested in a supine position for at least 30 minutes before the start of baseline blood pressure measurements. Blood pressure and heart rate measurements were obtained with an automated instrument (Vitastat model 900B, Indianapolis, Ind.) at 1-minute intervals throughout the protocol. The average of the first 10 minutes was the baseline pre-stress blood pressure and heart rate. This basal blood pressure was also designated the baseline pre-loading blood pressure. Mental stress was then induced by asking each subject to perform difficult mental arithmetic for a 10-minute period. The means of blood pressure and heart rate measurements during this phase were designated as the stress values. At completion of the mental arithmetic test, blood pressure and heart rate were recorded for a 5-minute period designated as the recovery period. The subject then stood up, and blood pressure and heart rate were recorded for another 5 minutes in the standing position; this phase was designated as the upright phase.

After the mental stress test, subjects were given instructions for sodium loading. They were asked to...
maintain their usual diet and consume 10 g NaCl/day, which was provided as 1 g NaCl matrix tablets (sodium chloride, Eli Lilly and Co., Indianapolis, Ind.). They were encouraged to drink fluid as needed to satisfy any additional thirst. Each subject was seen in 7 days for blood pressure and body weight measurements. On day 14 of sodium loading, the subjects underwent the final session. At this time, casual blood pressure and body weight were determined, and the mental stress testing protocol was repeated. A food questionnaire, developed to assess frequency of salty food intake, was administered before sodium loading and on days 7 and 14 to look for any significant deviation in the usual diet during sodium loading. Compliance with the sodium loading was checked by the timed overnight urine collections obtained before loading and on days 6, 7, 13, and 14. These samples were analyzed for sodium, potassium, and creatinine content.

This study was based on an unbalanced factorial design that consisted of race and blood pressure classification. Racial groups were balanced, with nearly equal distribution of men and women. The hemodynamic parameters, changes in those parameters, urine sodium, sodium:potassium (Na:K), and changes in sodium excretion were analyzed by a three-way analysis of variance (ANOVA) of blood pressure classification, race, and sodium sensitivity. Adjustments in means of differences in the covariates of age, sex, height, and preload body weight were determined with an analysis of covariance but provided negligible changes. Therefore, reported means are as observed. Correlations among all numerically continuous variables were analyzed using the Pearson r. Correlation coefficients and differences between means were considered significant for p<0.05.

**Results**

The completed cases included 83 blacks and 38 whites. Both blacks and whites were designated normotensive or marginally hypertensive on the basis of their usual seated blood pressure. Those with repeated seated mean arterial pressure (MAP) of less than 95 mm Hg were designated normotensive. An MAP greater than or equal to 95 mm Hg would reflect the upper quintile of the blood pressure distribution for young adults over an age of 18 years. In this study, those with an MAP of 95 mm Hg or greater were assigned to the marginally hypertensive group. With this classification, the normotensive group included 47 blacks and 30 whites. The hypertensive group included 36 blacks and eight whites. Table 1 provides average seated blood pressure, heart rate, body size, and age and sex distribution of the groups. As a group, the hypertensive subjects were taller and heavier than the normotensive ones. However, the hypertensive group comprised more men and the normotensive group more women. When body size measurements were compared among the groups by sex, both male and female hypertensive subjects were heavier, but this difference was not statistically significant.

Individual cases were then determined to be sodium-sensitive or sodium-insensitive on the basis of their change in MAP after sodium loading. By use of the criteria reported by Sullivan et al,7 subjects that had a 5% increase in presodium-loading MAP were considered sodium-sensitive. Subjects with a less than 5% increase in MAP were called sodium-insensitive. With these criteria, 18.4% of the white population and 37.3% of the black were sodium-sensitive.

Data on sodium excretion were analyzed for the normotensive and hypertensive subjects, which were subgrouped according to sodium sensitivity. Lower values of sodium excretion occurred in those with the greatest rise in blood pressure. There was a statistically significant correlation (r=-0.28, p<0.01) between the change in MAP and sodium excretion after sodium loading in the sodium-sensitive groups. Thus, the rise of MAP in the sodium-sensitive groups seems related to blunted sodium excretion.

Data on the cardiovascular response to neurogenic stress were analyzed according to similar blood pressure classification, race, and sodium sensitivity. These results are summarized in Figure 1, which presents the response to mental stress before and after sodium loading, with the population classified by sodium sensitivity. The presence of sodium sensitivity did not distinguish the blood pressure response to mental stress in either the normotensive or hypertensive populations. After sodium loading, the base-

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**Table 1. Study Subject Demographic Data**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Normotensive (n=78)</th>
<th>Hypertensive (n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White (n=30)</td>
<td>Black (n=48)</td>
</tr>
<tr>
<td>Males/females</td>
<td>12/18</td>
<td>19/29</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>19.7±1.8</td>
<td>20.8±1.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.6±12.4</td>
<td>69.3±14.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.3±8.4</td>
<td>168.7±10.2</td>
</tr>
<tr>
<td>BMI</td>
<td>22.1±3.9</td>
<td>24.4±5.1</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td>111±9.1</td>
<td>114.0±10.9</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td>71.0±6.8</td>
<td>71.0±6.9</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>65.5±8.9</td>
<td>67.5±10.8</td>
</tr>
</tbody>
</table>

Values are mean±SD. BMI, body mass index (wt/ht²); BP, blood pressure.
line MAP was higher in the sodium-sensitive groups. However, the MAP during stress was not significantly greater in the sodium-loaded condition. The only significant change that emerged after sodium loading was a greater upright MAP in the sodium-sensitive group compared with the sodium-insensitive groups ($p=0.005$). The stress response was replicated in the sodium-insensitive groups after the 2 weeks of sodium loading. Regardless of race, hypertensive subjects had a higher MAP than normotensive ones at each phase of the stress test ($p<0.01$). The reactivity (i.e., the change in MAP from baseline to stress) was also greater in hypertensive subjects. The reactivity was unchanged in all these groups after sodium loading. Therefore, sodium loading appeared to have no effect on the cardiovascular response to the stress of difficult mental arithmetic.

Discussion

The results of this investigation on sodium loading in young adults demonstrate a higher prevalence of sodium sensitivity in blacks (37%) than in whites (18%). Although no uniform definition of sodium sensitivity exists, the 5% or more increase in MAP that we used to determine sodium sensitivity is a pressure change consistent with other reports.19

In extensive studies of sodium loading and sodium depletion on an older adult population, Weinberger et al17 have described a greater prevalence of sodium sensitivity in both normotensive and hypertensive blacks. In their studies, a delay in excretion of an infused sodium load was characteristic of sodium-sensitive subjects. The present study demonstrates that sodium sensitivity is identifiable with a chronic oral method of sodium loading for younger-aged persons.

Several investigators have studied cardiac and peripheral hemodynamic characteristics of sodium sensitivity in human subjects. In normotensive persons, forearm vascular resistance falls as dietary sodium is increased.10 A high sodium intake in borderline hypertension results in an increase in forearm vascular resistance. These changes are augmented by norepinephrine infusion or sympathetic stimulation.11 Koolen and van Brummelen observed that salt-sensitive hypertensive patients had higher norepinephrine levels during their usual diet, and on high salt intake norepinephrine release increased.12

Mental arithmetic is considered an active-coping type of cognitive stressor and is associated with greater $\beta$-adrenergic responses.13 Several studies have reported a greater response to psychogenic stressors in borderline hypertensive persons than in normotensive ones.14 Light et al15 have investigated the cardiovascular response to active-coping stressors in college-age men, including normotensive blacks and whites, and marginally hypertensive groups. The systolic blood pressure response was greatest in the hypertensive blacks but without an attendant increase in heart rate. These investigators propose that the blunted heart rate response reflected greater peripheral vascular resistance in marginally hypertensive blacks.15 In our study, the MAP was greater during stress in hypertensive compared with normotensive blacks, but no difference in heart rate response was observed. The heart rate response to stress was greater in hypertensive whites than hypertensive blacks. However, the sample size of hypertensive whites was too small to determine levels of significance. The high sodium intake did not alter the $\beta$-adrenergic-mediated response to mental stress in race or blood pressure subgroups. The stress response, which was quantified as the change in blood pressure or heart rate from baseline during the central stimulus (mental arithmetic), was highly reproducible. The change was replicated within subjects and across groups regardless of baseline.

Recent evidence has emerged that $\alpha$-adrenergic activity may account for racial differences in cardiovascular response patterns. Anderson et al16 have found that young black normotensive adults show greater increases in blood pressure and forearm vascular resistance compared with whites in response to an ice pack on the forehead, a stimulus (like the cold pressor test) that elicits $\alpha$-adrenergic activity. Sullivan et al17 compared forearm vascular resistance in sodium-sensitive and sodium-insensitive subjects during a cold pressor test. In this predominantly white population, forearm vascular resistance increased in response to the cold pressor stimulus in the sodium-sensitive but not the sodium-insensitive subjects. In another recent investigation,Dimsdale et al18 investigated vascular sensitivity to infusions of the $\alpha$-agonist norepinephrine in blacks and whites under conditions of low and high dietary sodium.
During the infusion, hypertensive individuals had higher blood pressure at each norepinephrine dosage, but the slopes of the dose–response curves were the same for normotensive and hypertensive persons. However, with the high sodium intake, hypertensive blacks had an augmented blood pressure response to norepinephrine, whereas hypertensive whites had a reduced dose response to the same infusion. These reports demonstrate augmented α-receptor sensitivity in blacks and suggests that a variation in peripheral vascular response to α-adrenergic stimuli in blacks may exist that emerges under a high sodium condition.

The present study demonstrates that a sodium-sensitive blood pressure response can be identified by chronic oral sodium loading in some young adults. The prevalence of sodium sensitivity was greater in blacks than in whites. The data demonstrate that the pressor effect of a sodium load does not mediate an enhanced response to the β-adrenergic-mediated stimulus of mental arithmetic. These results suggest that, particularly in blacks, the blood pressure increase in response to sodium loading may be related to functional changes in peripheral vascular resistance.

References

KEY WORDS • sodium-dependent hypertension • stress • blood pressure • cardiovascular reactivity
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