Sodium Excretion and Racial Differences in Ambulatory Blood Pressure Patterns

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The influence of Na⁺ excretion and race on casual blood pressure and ambulatory blood pressure patterns was examined in a biracial sample of healthy, normotensive children and adolescents (10–18 years; n=140). The slopes relating 24-hour urinary Na⁺ excretion to systolic blood pressure were different for both black and white subjects for casual blood pressure (p<0.001) and blood pressure during sleep (p<0.03). For casual blood pressure, the slope was significant for black subjects (β=0.17; p<0.001) but not for white subjects. For blood pressure during sleep, the slope was again significant for black subjects (β=0.08; p<0.01) but not for white subjects. Na⁺ excretion was also related to awake levels of systolic blood pressure for black subjects (β=0.08, r=0.36; p<0.01), although the slopes for both black and white subjects were not significantly different. Further analyses indicated the results were not due to racial differences in 24-hour urinary K⁺ excretion. However, plasma renin activity was marginally related to Na⁺ excretion in white subjects (r=0.22; p<0.06) but not black subjects, a finding that is consistent with previous studies. Na⁺ excretion was not associated with diastolic blood pressure or heart rate in either group under any condition. The results of this study support research that has demonstrated a stronger relation between Na⁺ handling and casual blood pressure in black subjects and extend these findings to blood pressure while the subject is both awake and asleep. (Hypertension 1991;18:813–818)

Recent studies in both adolescents¹ and adults²,³ demonstrated that black subjects as a group had a "blunted" nocturnal decline in blood pressure (BP). Research has shown that Na⁺ intake is a primary determinant of BP in a significant percentage of both the hypertensive⁴,⁵ and normotensive⁶,⁷ populations, a characteristic referred to as "salt sensitivity." Furthermore, the prevalence of salt sensitivity has been found to be greater in the black population than in the white population.⁴,⁸ Therefore, the purpose of the present study was to examine the effect of sodium excretion (UNaV) and race on casual BP and ambulatory BP patterns in healthy black and white adolescents. In addition, K⁺ excretion (UKV)⁹–¹¹ and plasma renin activity (PRA)¹²–¹⁶ were measured to determine the role of these factors that are known to influence Na⁺ homeostasis and BP control.

Methods

Subject Characteristics and Casual Measurements

The protocol was approved by the Institutional Committee on Human Research and the Clinical Research Center Scientific Advisory Board. Written, informed parental consent was obtained before testing. The subjects were 199 healthy, normotensive children and adolescents recruited from churches, schools, and social organizations as described in detail.¹⁷ Of these, 19 subjects (10%) were excluded from the analyses due to questionable 24-hour recordings (see below); 40 subjects (20%) were excluded due to inadequate 24-hour urine collections (see below). Excluded subjects were similar in age, gender, BP, heart rate (HR), body surface area (BSA), and PRA to subjects included in the analyses. Health status was evaluated based on the subject's medical history and a brief physical examination to rule out the presence of cardiovascular or other abnormalities. The demographic characteristics and casual measurements from the subjects included in the analyses are provided in Table 1.

Casual Blood Pressure and Heart Rate

Casual BP and HR measurements were obtained with the Dinamap BP monitor (model 1846SX, Critikon, Tampa, Fla.) before the ambulatory BP re-
Data Analyses

Comparisons of subject characteristics were performed by analysis of variance on a Macintosh SE/30 computer with SUPERANOVA (Abacus Concepts Inc., Berkeley, Calif.). Overall analyses were performed by analysis of covariance using the SUPERANOVA program, using Type III sums of squares to test for main effects and interactions. The general form of the models included three factors: 1) race, 2) UNaV as a continuous variable, and 3) the interaction between race and UNaV to test if the slopes relating UNaV to BP in both black and white subjects were similar. (Note: when one of the independent variables is continuous and the other binary, the interaction term represents a test of the equality of the slopes between the two groups.) BSA was also included as a covariate in the models. The dependent variables included: 1) casual systolic BP (SBP), diastolic BP (DBP), and HR; 2) SBP, DBP, and HR while the subjects were awake; and 3) SBP, DBP, and HR while the subjects were asleep. Planned comparisons examining the slopes between UNaV and each dependent variable for both races were performed. A value of $p<0.01$ was considered significant. In addition, analyses were performed to test the relation between UNaV and both UNaV and PRA. Finally, separate models were run substituting UKV for UNaV in the general model to examine the relation between UKV and ambulatory BP patterns.

Results

Race, Age, Gender, Body Surface Area, and Sodium Excretion

The black subjects were older than the white subjects, with greater BSA (Table 1). The correlation between age and BSA was significant ($r=0.60$; $p<0.01$). There was a higher percentage of girls among the black subjects and a higher percentage of boys among the white subjects. UNaV was similar for black and white subjects (Table 1).

Race, Sodium Excretion, and Casual Blood Pressure

The effects of both race ($p<0.01$) and UNaV ($p<0.001$) on casual SBP were significant. In addition, the race by UNaV interaction was significant ($p<0.001$), indicating that the slopes between UNaV and SBP were different for black and white subjects. The slope was positive and significant for black subjects ($p<0.001$); the slope was not significant for white subjects (Figure 1). Further analyses were...
performed with the inclusion of gender in the model to control for group differences on this variable. The race by \(\text{UNaV}\) interaction remained significant \((p<0.01)\). Although the effect of gender was significant \((p<0.01)\), the interaction among race, \(\text{UNaV}\), and gender was not significant. Significant effects were not found for either DBP or HR.

**Race, Sodium Excretion, and Ambulatory Blood Pressure While Awake**

The effects of race, \(\text{UNaV}\), and the interaction between race and \(\text{UNaV}\) were not significant for SBP while the subjects were awake. However, further analysis indicated that the slope relating \(\text{UNaV}\) to awake SBP was positive and significant for the black subjects (Figure 2). Similar results were obtained after the inclusion of gender \((p=\text{NS})\) in the model. Significant effects were not found for either DBP or HR.

**Race, Sodium Excretion, and Ambulatory Blood Pressure While Asleep**

The effect of \(\text{UNaV}\) on SBP while the subjects were asleep was significant \((p<0.01)\). In addition, the race by \(\text{UNaV}\) interaction was significant \((p<0.03)\), indicating that the slopes between \(\text{UNaV}\) and SBP were different for both black and white subjects. The slope was positive and significant for black subjects \((p<0.01)\); the slope was not significant for white subjects (Figure 3). The race by \(\text{UNaV}\) interaction remained significant \((p<0.03)\) after the inclusion of gender \((p=\text{NS})\) in the model. Significant effects were not found for either DBP or HR.

**Race, Sodium Excretion, and Plasma Renin Activity**

Both black and white subjects had similar levels of PRA (Table 1). The slope relating PRA to \(\text{UNaV}\) was negative for the white subjects and approached statistical significance \((r=-0.22; p<0.06)\). PRA and \(\text{UNaV}\) were not related for black subjects \((r=0.07)\).

**Race, Sodium Excretion, Potassium Excretion, and Blood Pressure**

Black subjects had significantly lower levels of \(\text{UKV}\) than white subjects (Table 1). The slopes relating \(\text{UNaV}\) to \(\text{UKV}\) were similar for black subjects \((\beta=1.360; p<0.001)\) and for white subjects \((\beta=1.662; p<0.001)\), with a higher intercept for the black subjects \((97.21 \text{ meq/24 hr})\) than for white subjects \((58.8 \text{ meq/24 hr})\). In addition, \(\text{UKV}\) was not related to any measure of BP (casual, awake, or asleep) for either group.

**Discussion**

The increased prevalence of essential hypertension among black adults is well documented.\(^{20}\) Previously, we demonstrated that healthy normotensive black adolescents have higher levels of BP than white individuals at night, despite similar levels of BP during the day.\(^{1}\) Furthermore, we\(^{2}\) and others\(^{3}\) demonstrated that healthy, normotensive black adults have a smaller nocturnal decline in BP than previously observed in white adults.\(^{21-25}\) Based on these observations, we hypothesized that the additional “cardiovascular strain” resulting from the blunted nocturnal decline in BP among black individuals may be a contributing factor to the racial difference in the prevalence of hypertension.\(^{2}\)
The present study suggests that Na\(^+\) handling and regulation contribute to the racial differences in ambulatory BP patterns. The slopes relating U\(_{Na}\)V to SBP were different for both black and white subjects. Specifically, U\(_{Na}\)V was related to casual SBP in black subjects, with higher levels of Na\(^+\) intake (as determined by U\(_{Na}\)V) associated with higher levels of SBP. Similar relations were found between U\(_{Na}\)V and SBP while awake and U\(_{Na}\)V and SBP while asleep. In contrast, U\(_{Na}\)V was not related to SBP for white subjects under any condition.

These findings are consistent with the only study to our knowledge to examine the influence of Na\(^+\) intake on 24-hour BP. In that study, 20 healthy subjects had 24-hour recordings performed before and after Na\(^+\) restriction (107 versus 11 meq/24 hr). The mesor (a "running mean") for SBP was significantly lower after the reduction in Na\(^+\) intake (115 versus 104 mm Hg). As in the present study, DBP was not affected. It should be noted that the previous study was performed under hospital conditions and required the subjects to remain in a reclining position throughout the recording.

These findings are also consistent with research indicating that Na\(^+\) handling contributes to racial differences in the prevalence of essential hypertension. The studies of Luft and his colleagues demonstrated that black subjects as a group were more salt-sensitive (SS) than white subjects as a group. The black subjects excreted significantly less Na\(^+\) than white subjects the first 10 hours and 24 hours after Na\(^+\) loading. The delayed excretion of the Na\(^+\) load of the black subjects was associated with a greater increase in BP. In addition, they demonstrated that a diet of 800 meq of Na\(^+\) was needed to raise BP for black subjects compared with a diet of 1,200 meq Na\(^+\). A correlation between UNaV and SBP while asleep. In addition, they demonstrated that a diet of 800 meq of Na\(^+\) was needed to raise BP for black subjects compared with a diet of 1,200 meq Na\(^+\). A correlation between UNaV and SBP while asleep. 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The influence of Na+ on BP may be mediated by K+. Morgan and his colleagues9,10 demonstrated that K+ supplementation prevents Na+-induced rises in BP in people with SS hypertension. In addition, Svetkey et al11 showed that K+ supplementation was more effective in reducing BP in black than in white adults with mild hypertension. In the current study, black subjects were characterized by lower levels of UNaV. However, the slopes relating UNaV to UNaV were positive and similar for both black and white subjects, suggesting that the influence of K+ on Na+ handling was similar. In addition, UNaV was not related to casual, awake, or asleep BP in either black or white subjects after adjustment for body size.

In summary, the results of the current study suggest that Na+ handling is one factor responsible for racial differences in ambulatory BP patterns in children and adolescents. Within black subjects, the relation between UNaV and BP was positive and linear for casual SBP, awake SBP, and asleep SBP. In contrast, UNaV was not associated with SBP in white subjects under any condition. UNaV was not associated with DBP or HR in either group under any condition. Further analyses indicated these results were not due to racial differences in UNaV but were consistent with the hypothesis that black individuals do not adequately suppress PRA in response to increases in Na+ intake.

Interpretation of these results must take into account the cross-sectional design of the study. Further research is needed to determine if directly manipulating Na+ intake in black subjects will increase awake and asleep BP but will not change BP in white subjects. In addition, UNaV was collapsed across 24-hour periods, which did not allow us to examine directly the relation between UNaV and BP under each condition. Additional studies are needed to determine if UNaV while awake is directly related to BP while awake and if UNaV during sleep is directly related to BP during sleep. However, the results are consistent with the literature demonstrating the importance of Na+ on the regulation of BP for black individuals and extends these results to BP while awake and while asleep.

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