Threshold Effects of Dietary Calcium on Blood Pressure

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The relationships of calcium and dietary sodium, potassium and alcohol to blood pressures were studied at three different levels of dietary calcium intake by adults in the Health and Nutrition Examination Survey (HANES) I sample. At low calcium intakes (<400 mg/day), after adjustment for age and body mass index, the strongest dietary correlates of blood pressure were the ratio of sodium to potassium (Na:K), and alcohol ($P < 0.01$). At higher calcium intakes alcohol, but not Na:K, was significantly related to blood pressures. Neither sodium nor potassium was separately related to blood pressure when the Na:K ratio was included in the regression model. The threshold effect of calcium was observed in all race–gender groups. These results indicate: (1) the Na:K is a more important correlate of blood pressure than either nutrient alone; and (2) a low calcium intake is necessary for the Na:K ratio to maximally affect blood pressure.

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Introduction

There is evidence to suggest that an excessive sodium intake is perhaps the most important dietary influence contributing to higher blood pressures [1]. In addition, alcohol, potassium, the Na:K ratio and calcium are other dietary factors that have been strongly associated with elevated blood pressures [2–7]. Higher alcohol and sodium intakes, as well as a higher Na:K ratio, have been related to higher blood pressure levels, but an inverse relationship has been observed between potassium intake and blood pressure. When detected, the relationships between calcium and blood pressure have been inverse, with a lower calcium intake associated with higher blood pressures.

The first Health and Nutrition Examination Survey (HANES I), conducted from 1971 to 1974, obtained comprehensive dietary information and other data on a probability sample of US residents [8]. These data were used to evaluate the relationships of age, body mass index and dietary factors to blood pressure at three different levels of calcium intake.

Methods

Computer files were created from HANES I data by merging the following tapes: dietary frequency and adequacy (tape 4701), medical history (tape 4081) and medical examination (tape 4233). Adults aged 18–74 years were studied. However, respondents who were on special diets (n = 1944), who had daily calorie intakes of <700 or >5000 (n = 851), who were taking medication for hypertension (n = 889), or for whom no age was given at medical examination (n = 2126) were excluded. After these exclusions, there were 9553 respondents eligible for study. Nutrient and total calorie intakes were estimated from 24-h dietary recall interviews. Alcohol consumption was derived from a series of four quantity-frequency questions on the medical history interview.

Systolic blood pressure was analysed as a continuous variable. The body mass index was measured as weight/height^2, after conversion of weight from pounds to kilograms (1 lb = 0.454 kg) and height from inches to metres (1 in. = 0.0254 m).

The racial categories supplied with the survey data were 'white', 'black' and 'other'. Since respondents in the 'other' category accounted for only 7% (n = 136) of the non-whites and 1% of the total study cohort, they were included with whites in a single category.

Results

Multiple regression analysis was used to assess the relationships of age, the body mass index and dietary variables to systolic and diastolic pressure variables. In these regression models, age and body mass index were

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the strongest predictors of blood pressure, with alcohol consumption and the Na:K ratio being the only significant dietary variables to predict systolic blood pressure; for diastolic blood pressure, alcohol was the only significant dietary variable. The intakes of sodium, potassium and calcium by themselves were not statistically significant predictors of blood pressure. However, without the Na:K ratio in the regression equation, both sodium and potassium were significantly related to systolic blood pressure: sodium was directly related and potassium was inversely related.

To test the hypothesis that there may be a threshold level of calcium intake, above which blood pressure may not be influenced by nutrients, respondents were categorized by daily calcium intake, with about 1/3 of the study sample in each category. The categories of calcium intake were: <400, 400–800 and >800 mg. Nearly 2/3 of all respondents in the study sample reported calcium intakes below the minimum daily intake of 800 mg recommended by the Food and Nutrition Board of the National Academy of Sciences [9]. By examining the variations in calcium intake between race–gender groups, we found significantly more men than women with intakes above the recommended 800 mg, and more whites than blacks. The highest proportion of subjects with a calcium intake above the recommended level was that of white men, nearly half of whom had a high calcium intake. The lowest proportion with a calcium intake > 800 mg was that of black women, with only about 13% above the recommended level.

When the relationships between the nutrient variables and blood pressure were evaluated according to level of calcium intake, a distinct pattern emerged. By examining the Na:K ratio across the three groups of calcium intake, we observed that in the lowest calcium-intake group the regression coefficient for systolic blood pressure was 2.88 and statistically significant ($P < 0.01$). In comparison, in the middle calcium-intake group, the regression coefficient of Na:K on systolic blood pressure dropped to 0.95, and the significance level was about 0.07. At the highest calcium-intake level, the regression coefficient for Na:K on systolic blood pressure was only 0.01 and was not statistically significant ($P < 0.05$). In summary, a gradient was evident, with the Na:K ratio exhibiting progressively lower degrees of association with blood pressure at the higher levels of calcium intake. A similar gradient was evident for diastolic blood pressure. In contrast, age, the body mass index and alcohol were significantly related to both systolic and diastolic blood pressure, regardless of calcium level. Intakes of individual nutrients including sodium, calcium, phosphorus and potassium were not as strongly correlated with blood pressure as the Na:K ratio, and were not statistically significant in these equations.

The threshold effect of calcium intake on the relationship between the Na:K ratio and blood pressure was more evident when mean systolic and diastolic blood pressure was compared between the lowest and highest quartiles of the Na:K ratio, within each level of calcium intake (Fig. 1). For a calcium intake < 400 mg, individuals with high Na:K ratios had significantly higher systolic and diastolic blood pressure than those with low ratios; for a calcium intake between 400 and 800 mg, systolic

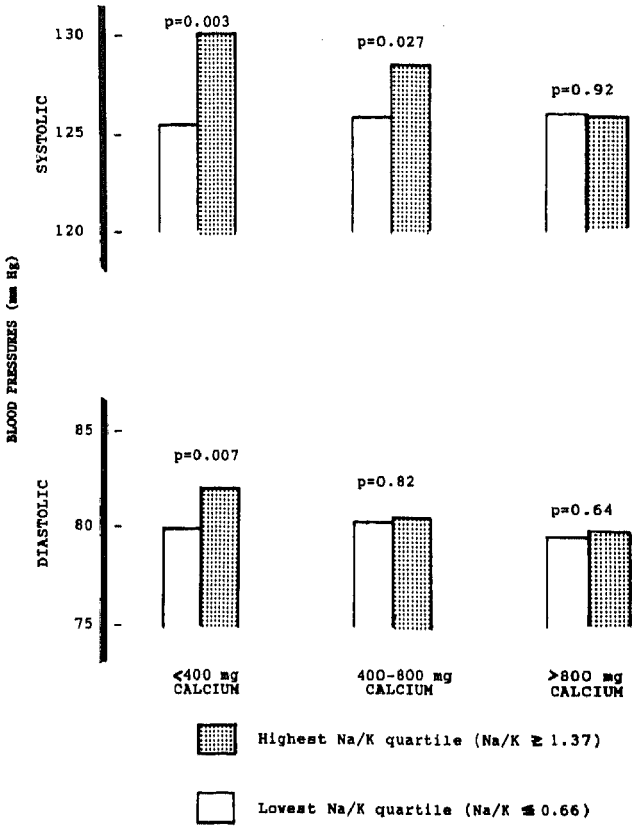

Fig. 1. Comparisons of blood pressure between lowest and highest sodium:potassium ratio (Na/K) quartiles for HANES I respondents according to daily calcium intake levels.

blood pressure (but not diastolic) was significantly different between the high and the low Na:K ratios; for a calcium intake > 800 mg, there were no statistically significant differences in either systolic or diastolic blood pressure between individuals with high and low ratios.

Separate stratified analyses of the low-calcium group by race–gender categories revealed a similar pattern of higher blood pressure with high Na:K ratios, and in three of the four categories the higher pressures were statistically significant. The only exception was the category white men, where the difference in systolic blood pressure between high and low Na:K quartiles was less than in the other categories. This indicates that the influence of the Na:K ratio on blood pressure was perhaps not as important as other factors, such as the body mass index and alcohol intake, for white men. Moreover, these men had a higher calcium intake and a higher alcohol intake than the other race–gender categories, and these factors might have diminished the impact of the Na:K ratio on blood pressure. Diastolic pressure was also higher in the upper Na:K quartile in all four race–gender categories, although statistical significance was achieved only for women.

Discussion

The results of our analyses indicate that:

(1) the ratio of dietary Na:K is a significant independent correlate of both systolic and diastolic blood pres-

sure, and is a stronger predictor of blood pressure than either nutrient alone; and

(2) the strength of the association between the Na:K dietary ratio and blood pressure was inversely related to dietary calcium intake, with the strongest effect of the Na:K ratios evident in the lowest calcium-intake group

There was no effect from the calcium level on the other correlates of blood pressure. Age, the body mass index and alcohol intake were each independently associated with blood pressures regardless of calcium intake.

Our interpretation of these findings is the following. First, the observed associations from cross-sectional data are suggestive but not sufficient evidence for causality. Second, the relationships between dietary, serum and cellular levels of these nutrients are not understood. At this time there is no evidence for direct linkage between dietary intakes of nutrients and cellular concentrations, where the physiological effect presumably occurs. Third, by presenting these results we hope to stimulate further epidemiological and experimental studies on the interrelationships between sodium, potassium and calcium relative to blood pressure. Since there are several pathological mechanisms that can lead to increased blood pressure, it seems probable that the nutrients may have different degrees of importance depending on the mechanism [10]. However, a better understanding of dietary risk factors for elevated blood pressure may lead to the development of intervention strategies to reduce the prevalence of hypertension in the US population.

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