Effect of Potassium Intake on Blood Pressure

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ABSTRACT
Epidemiologic, experimental, and clinical studies suggest that potassium is an important regulator of blood pressure. Surveys conducted in widely divergent geographic locations indicate higher prevalence of hypertension in populations ingesting diets low in potassium. Amelioration of hypokalemia lowers blood pressure in mineralocorticoid-induced hypertension in rats and in essential hypertensive patients receiving thiazide diuretics. We observed that in normotensive subjects ingesting normal amounts of sodium, short-term potassium depletion increases the mean arterial pressure from 90.9 ± 2.2 mm Hg to 95.0 ± 2.2 mm Hg (P < 0.01). Furthermore, acute sodium loading increases blood pressure in potassium-depleted subjects but it had no effect in subjects ingesting normal amounts of potassium. Preliminary studies indicate that short-term potassium depletion also elevates blood pressure in hypertensive patients. Potassium supplementation lowers blood pressure in hypertensive patients ingesting normal amounts of sodium. Blacks appear to be more sensitive to the hypotensive effects of potassium.

The mechanism of potassium-induced changes in blood pressure is not well understood. Potassium depletion consistently induces sodium retention. The hypertensive effects of potassium depletion and hypotensive effects of potassium supplementation are not observed when sodium intake is kept low. Direct vasoconstrictive effects of hypokalemia may contribute to the pressor effect of potassium depletion. The role of altered vascular sensitivity to vasoactive hormones and alterations in divalent cation metabolism in mediating the potassium-induced changes in blood pressure require further study.

KEY WORDS: Hypertension, hypokalemia, sodium, renin, calcium

The role of electrolytes such as sodium, chloride, and calcium in the pathogenesis of hypertension is well recognized. Evidence accumulated over the past 3 decades strongly suggests that potassium intake plays an important role in blood pressure regulation in humans. Several epidemiologic, experimental, and clinical studies confirm the role of potassium in the pathogenesis of hypertension.

EPIDEMIOLOGIC STUDIES
Epidemiologic surveys from widely divergent geographic locations within and outside the United States have demonstrated an inverse correlation between potassium intake and the prevalence of hypertension. Lever et al. (1) measured exchangeable total body sodium and potassium and correlated these measurements to blood pressure in 121 normotensive and 91 hypertensive subjects. Blood pressure correlated positively with the total body sodium and negatively with the total body potassium. Walker and colleagues (2) surveyed 574 ambulatory subjects with blood pressure values ranging from 94/58 mm Hg to 250/145 mm Hg. An inverse relationship was noted between urinary potassium excretion and diastolic blood pressure. Urinary potassium excretion was significantly lower in hypertensive subjects compared with the values noted in normotensive subjects. Similar surveys conducted in Japan, Korea, Belgium, and China confirm the inverse correlation between potassium intake and blood pressure (3–7). Surveys conducted in Hawaii and Southern California discovered similar correlations (8,9). A strong negative correlation was also reported between serum potassium concentration and blood pressure in a large Belgian study (10) and a study from Japan (11). More recently, in a large international collaborative study, samples were obtained for 24-h urinary electrolyte excretion rates from 10,079 adults from 52 centers (12). The relationship between electrolyte excretion and blood pressure was studied in each center and the results from all 52 centers were pooled. Blood pressure correlated positively with sodium intake and negatively with potassium intake.

Lower potassium intake has been implicated in the higher prevalence of hypertension among blacks (13–17). Langford and Watson (13) studied the blood pressures and 24-h urinary electrolyte excretion rates in 104 black women living in Mississippi. The diastolic blood pressure correlated strongly with the sodium-to-potassium excretion ratio. Grim et al. (14) assessed the dietary intake of sodium and potassium by collecting duplicate diets and 24-h urine samples.
Blacks and whites from Georgia were ingesting similar quantities of sodium, but potassium intake in blacks was consistently lower. The prevalence of hypertension in the black population, not unexpectedly, was higher than in white population. Surveys conducted in Indiana and Louisiana and the data obtained from a National Health and Nutrition Examination Survey confirm that urinary potassium excretion is lower in blacks compared with that of whites living in similar geographic locations (15–18). These studies suggest that the higher prevalence rates of hypertension in blacks might be related to the lower potassium intake.

In summary, epidemiologic studies strongly suggest a protective effect of high potassium intake against the genesis of hypertension. However, correlations obtained in these studies do not establish a causal association. Diets low in potassium might be different in the quantities of other nutrients, each of which may play a role in the pathogenesis of hypertension. Only longitudinal studies over time can establish the specificity of potassium-induced changes in blood pressure. Accordingly, several experimental and clinical studies have investigated the effect of potassium depletion and potassium supplementation on blood pressure.

**EXPERIMENTAL STUDIES**

**Potassium Depletion**

Severe potassium depletion in Long-Evans rats retards their growth and lowers blood pressure (19, 20). Linas and colleagues (21, 22) noted similar decreases in blood pressure in normotensive rats and in rats made hypertensive from unilateral clipping of the renal artery. The decrease in blood pressure in these rats is associated with a decrease in peripheral vascular resistance and impaired pressor response to angiotensin II (21–24). Hypotensive effects of potassium depletion have also been demonstrated in spontaneously hypertensive rats (25). Potassium depletion in dogs is associated with a decrease in blood pressure (26) along with a modest decrease in cardiac output (27). However, potassium depletion induced by mineralocorticoid administration is associated with an increase in blood pressure. Fujita and Sato (28) studied uninephrectomized Sprague-Dawley rats receiving 1% sodium chloride solution to drink. Administration of deoxycorticosterone acetate (DOCA) for 28 days induced potassium depletion, sodium retention, and elevations in systolic blood pressure to 177 ± 3 mm Hg. Potassium chloride supplementation as 0.2% or 1% solution to drink attenuated the hypokalemia and lowered the systolic pressure to 131 ± 3 mm Hg and 120 ± 3 mm Hg, respectively (Figure 1). In addition, potassium supplementation attenuated the sodium retention accompanying the mineralocorticoid therapy. Potassium citrate administration exerted a similar hypotensive effect, suggesting that the beneficial effect of potassium salts results from the cation (28). Thus, amelioration of hypokalemia attenuates the mineralocorticoid-induced sodium retention and hypertension in rats.

**Potassium Supplementation**

In contrast to the variable effects of potassium depletion on blood pressure, potassium supplementation lowers blood pressure in several models of experimental hypertension. Meneely and Ball (29) measured systolic pressure in Sprague-Dawley rats ingesting high-sodium diets. Rats ingesting these diets over several months developed hypertension. Increasing the potassium intake lowered the blood pressure and improved their survival. Subsequent studies demonstrated that increased potassium intake lowered the total body exchangeable sodium (30, 31). Dahl et al. (32) made similar observations in salt-sensitive rats fed high-sodium diets. Increasing the dietary potassium content attenuated the hypertensive effect of high-sodium diet. Potassium supplementation in spontaneously hypertensive rats attenuated the increase in blood pressure and decreased the exchangeable sodium content (33). Workman and Paller (34) noted that potassium supplementation markedly reduced the peripheral vascular resistance in these rats. Suzuki et al. (35) administered potassium chloride to Wistar rats with two-kidney and one-clip renovascular hypertension. Potassium supplementation prevented the development of hypertension and reversed the established hypertension in these rats. Anderson et al. (36) made a group of dogs...
hypertensive by a combination of avoidance conditioning and saline infusion. Increasing the potassium intake in these dogs markedly lowered the magnitude of blood pressure elevation.

In summary, potassium supplementation lowers blood pressure in experimental models of hypertension whereas potassium depletion has a variable effect. In experimental hypertension associated with sodium retention such as mineralocorticoid-induced hypertension, potassium depletion increases blood pressure. In renovascular hypertension and in spontaneously hypertensive rats both potassium depletion and potassium supplementation lower blood pressure.

**CLINICAL STUDIES**

**Potassium Depletion**

In contrast to the abundant literature documenting the hemodynamic effects of potassium depletion in animals, the information available in humans is very limited. Perera (37) noted a decrease in blood pressure in four hypertensive subjects ingesting a low-potassium diet. However, all these subjects were ingesting diets low in sodium. Thus, potassium depletion did not modify the hypotensive effects of sodium restriction. We made similar observations in normotensive subjects ingesting low-sodium diets (38). To investigate the blood pressure response to potassium depletion in subjects ingesting a normal sodium diet, we undertook the following studies at the General Clinical Research Center (GCRC) of Temple University Hospital.

**Effect of Potassium Depletion on Blood Pressure on Normal Sodium Intake (39)**

Ten healthy normotensive men ranging in age from 20 to 40 yr were studied at the GCRC. After verification of external sodium and potassium balance, subjects were admitted to the GCRC, and base-line measurements for plasma electrolytes and blood pressure were obtained. For the next 9 days subjects ingested diets providing 0.5–0.7 g/kg body wt protein, 30–35 kcal/kg body wt energy, 10 mEq of potassium, 400 mg of calcium, and 500 mg of phosphorous per day. The sodium content of the diets ranged between 120 and 200 mEq per day and closely matched the subjects' usual intake. This amount was kept constant for each subject during both study periods.

Each subject was studied on two occasions 4–8 weeks apart. One protocol required the ingestion of 10 placebo tablets per day in three divided doses with the diet supplying 10 mEq of potassium. The second protocol required the ingestion of 10 potassium chloride tablets (8 mEq each) per day in three divided doses. Each subject participated in both protocols in a randomized sequence and was unaware of the composition of the tablets. Thus, the intake of potassium was maintained at either 10 mEq or 90 mEq per day. On day 1 and day 10, blood pressure measurements were obtained on a Datascope Accutorr 1 blood pressure monitor. Three readings were obtained in each position: supine, seated, and upright posture. To study the blood pressure response to acute sodium loading on day 10, subjects received a 2-L isotonic saline infusion over 4 h. Changes in blood pressure were monitored during the infusion.

Ingestion of a low-potassium diet induced a negative potassium balance and a reduction in plasma potassium concentration of 0.6 mEq/L. The systolic and diastolic blood pressures were similar before entry into the two treatment protocols (Figure 2). On normal potassium intake, compared with pre-study values, the post-study values for systolic pressure (121.0 ± 2.0 vs. 120.0 ± 2.5 mm Hg), diastolic pressure (76.3 ± 1.8 vs. 73.1 ± 2.5 mm Hg), and mean arterial pressure (91.1 ± 1.8 vs. 88.9 ± 2.3 mm Hg) were lower but the differences did not reach statis-
tical significance. In sharp contrast, on the low-potassium diet, the systolic pressure (119.4 ± 2.8 vs. 125.5 ± 3.6 mm Hg), diastolic pressure (76.9 ± 2.0 vs. 80.5 ± 2.1 mm Hg), and mean arterial pressure (90.0 ± 2.2 vs. 95.0 ± 2.2 mm Hg) increased significantly (P < 0.05) over the pre-study values. Furthermore, the post-study levels of diastolic and mean arterial blood pressures on low-potassium intake were significantly (P < 0.01) higher than those on the normal potassium intake.

In response to saline infusion, mean arterial pressure rose significantly (P < 0.02) over the pre-infusion values when the subjects ingested low-potassium diets (Figure 3). In contrast, acute sodium loading failed to alter the blood pressure when the subjects ingested a normal potassium diet. Furthermore, the mean arterial pressure noted on the low-potassium diet was significantly higher than the corresponding values noted on the normal potassium diet during the 2nd (P < 0.01), 4th (P < 0.025), and 6th (P < 0.001) h of the infusion. These studies demonstrate that short-term potassium depletion increases both systolic and diastolic blood pressure in normotensive subjects ingesting normal amounts of sodium. In addition, potassium depletion sensitized these subjects to the blood pressure-raising effects of acute sodium loading.

We have recently demonstrated that potassium depletion exerts similar hypertensive effects in subjects with essential hypertension (40). Eight subjects with essential hypertension receiving no medications in-

![Figure 3. Mean arterial pressure in response to 2-L isotonic saline infusion over 4 h in normotensive subjects ingesting normal (closed circles) or low- (open circles) potassium diet. The shaded area represents the period of saline infusion. (Krishna et al. (39),) Reprinted by permission of The New England Journal of Medicine.)](image-url)

gested isocaloric diets providing either 96 mEq/day or 16 mEq/day potassium for 10 days. Low-potassium diets induced potassium depletion and sodium retention. The mean arterial pressure on day 11 was significantly higher on the low-potassium diet (107 ± 2 vs. 113 ± 2 mm Hg, P < 0.05). In response to a 2-L isotonic saline infusion, mean arterial pressure rose on both diets but reached higher levels on the low-potassium diet (110 ± 2 vs. 115 ± 2 mm Hg, P < 0.05). The sodium retentive and hypertensive effects of potassium depletion could not be explained by changes in plasma renin activity, arginine vasopressin, or renal hemodynamics.

Lawton et al. (41) recently reported similar observations in normotensive and essential hypertensive subjects. The sodium intake was kept high (400 mEq/day), whereas potassium intake was maintained at low (30 mEq/day) or normal (100 mEq/day) levels for 5 days. The ambulatory systolic blood pressures were significantly higher on low potassium intake in normotensive and hypertensive subjects. The differences in diastolic blood pressure on varying potassium intake did not reach statistical significance. The weight gain and decrease in hematocrit noted on low-potassium intake indicate expansion of extracellular fluid volume.

**Potassium Supplementation**

The effect of increased potassium intake on blood pressure has been investigated in normotensive and hypertensive subjects (42-57). Kempner (42) noted a decrease in blood pressure in hypertensive subjects ingesting a diet rich in potassium and low in sodium, fat, and protein. However, the relative importance of various nutrients in lowering blood pressure could not be assessed from this study. High potassium intake lowered blood pressure in essential hypertensive subjects on a normal sodium intake (43-51). Svetkey et al. (48) administered either placebo or potassium chloride (120 mEq/day) to 101 adult hypertensive subjects in a randomized, double-blind manner. A significant fall in systolic (6 mm Hg) and diastolic (4 mm Hg) pressures was noted on potassium chloride therapy, whereas the pressures were unchanged on placebo. Blacks appear to be particularly sensitive to the blood pressure-lowering effects of potassium (48). A 19-mm Hg decrease in systolic pressure and a 13-mm Hg decrease in diastolic pressure were noted in the five black subjects receiving potassium chloride.

Kaplan and colleagues (56) investigated the effect of potassium supplementation on blood pressure in hypertensive subjects who became hypokalemic while receiving thiazide diuretics. In a randomized, double-blind, cross-over trial 16 essential hypertensive subjects received either placebo or potassium chloride (60 mEq/day) for 6 weeks. When the subjects
TABLE 1. Mechanism of Potassium-Induced Changes in Blood Pressure

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Description</th>
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<tbody>
<tr>
<td>Sodium excretion</td>
<td>Potassium depletion: ↓ sodium excretion</td>
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<tr>
<td>Potassium supplementation: ↑ sodium excretion</td>
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<td>Vasoactive hormones</td>
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<td>Plasma renin activity: Variable response in humans</td>
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<tr>
<td>Catecholamines: Changes determined by alterations in sodium balance.</td>
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<tr>
<td>Altered vascular response to vasoactive hormones</td>
<td>Potassium supplementation: ↑ pressor response to angiotensin II and norepinephrine</td>
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<tr>
<td>Direct vascular effect</td>
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<td>Hypokalemia: vasoconstrictor</td>
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<tr>
<td>Hyperkalemia: vasodilator</td>
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<tr>
<td>Altered divalent ion metabolism</td>
<td>Potassium depletion: ↑ urinary calcium excretion</td>
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<td>Potassium supplementation: ↓ urinary calcium excretion</td>
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*↑ indicates increase, ↓ indicates decrease.

Sodium Excretion

Changes in potassium intake produce striking alterations in sodium balance (38–40, 58–61). Sodium retention, a consistent feature of potassium depletion, increases blood pressure by (a) increasing extracellular fluid volume, (b) altering the pressure-natriuresis relationship, (c) increasing intracellular sodium concentration, and (d) stimulating the release of a circulating Na⁺-K⁺-ATPase inhibitor. We measured urinary sodium and potassium excretion rates in subjects ingesting normal and low-potassium diets (39). The subjects excreted significantly less sodium on the low-potassium diet compared with the amounts excreted on the normal potassium diet. The differences were significant as early as the 1st day of the study and remained significant at the end of the study period. Over the 9-day study period subjects ingesting low-potassium diets developed a cumulative positive sodium balance of 396 mEq and a negative potassium balance of 297 mEq. The cumulative cation balance (sodium gain minus potassium loss) was positive and this was matched by the retention of an equivalent amount of chloride. Thus, we estimated that approximately 99 mEq (396 mEq–297 mEq) of sodium chloride were retained in the extracellular space on the low-potassium diet. The major portion of retained sodium must have replaced the potassium lost from the cells. The role of increased intracellular sodium in mediating the blood pressure increase is unknown. We observed that potassium depletion also attenuates the natriuretic response to acute sodium loading (38, 39). In response to saline infusion, subjects ingesting a low-potassium diet excreted significantly lesser amounts of sodium compared with the values noted on a normal potassium intake.

Dietary sodium intake modifies the hypertensive

MECHANISM OF POTASSIUM-INDUCED CHANGES IN BLOOD PRESSURE

The mechanism of blood pressure increase during potassium depletion is unclear. Sodium retention, changes in vasopressor hormones, direct effects on vasculature, and alterations in divalent ion metabolism are potential factors (Tables 1 and 2).
TABLE 2. Relationship between Potassium Intake and Blood Pressure

<table>
<thead>
<tr>
<th>Model Studied</th>
<th>Change in Blood Pressurea</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Animal studies</td>
<td></td>
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<tr>
<td>Potassium depletion</td>
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<tr>
<td>Normal saline intake</td>
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<tr>
<td>Normotensive subjects</td>
<td>↓</td>
<td>19, 20, 21, 26</td>
</tr>
<tr>
<td>Hypertensive subjects</td>
<td>↑</td>
<td>28</td>
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<tr>
<td>Low sodium intake</td>
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<td></td>
</tr>
<tr>
<td>Normotensive subjects</td>
<td>↔</td>
<td>38</td>
</tr>
<tr>
<td>Hypertensive subjects</td>
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<td>37</td>
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<tr>
<td>Potassium supplementation</td>
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<tr>
<td>Normal saline intake</td>
<td></td>
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</tr>
<tr>
<td>Normotensive subjects</td>
<td>↓ or ↔</td>
<td>54, 55, 57</td>
</tr>
<tr>
<td>Hypertensive subjects</td>
<td>↓</td>
<td>43–51</td>
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<tr>
<td>Low sodium intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertensive subjects</td>
<td>↔</td>
<td>52, 53</td>
</tr>
</tbody>
</table>

a ↑ indicates increase, ↓ indicates decrease, ↔ indicates no change.

effects of potassium depletion. To study the effects of potassium depletion on a low sodium intake, we studied seven healthy men at the GCRC (38). Before entry into the study these subjects were ingesting diets providing 200 mEq of sodium and 80 mEq of potassium daily. The subjects were then placed on an isocaloric diet providing 35 mEq/day sodium for 9 days. The potassium intake was maintained at 10 mEq/day or 90 mEq/day. In response to dietary sodium restriction, mean arterial pressure decreased by 3 mm Hg, and this decrease in pressure was identical on both normal and low potassium intake. Thus, the hypertensive effects of potassium depletion were not observed in subjects ingesting lowsodium diets. Similarly, hypotensive effects of potassium supplementation in essential hypertensive subjects are also not observed if their sodium intake is kept low (52, 53).

Although sodium retention contributes to the hypertensive effects of potassium depletion, other factors must play a role. As discussed above, the extra-cellular fluid (ECF) expansion during potassium depletion is small. Isotonic retention of 99 mEq of sodium chloride in ECF produces a meager 4%–5% increase in volume. We found no relationship between the amount of sodium retained and the increase in blood pressure during potassium depletion. Finally, expansion of the ECF by isotonic saline infusion increased blood pressure only in potassium-depleted subjects, whereas blood pressure in subjects ingesting normal amounts of potassium was unchanged.

Vasoactive Hormones

Renin-Angiotensin System. Potassium depletion increases plasma renin activity in rats (62, 63). Sealey et al. (62) varied the potassium intake of rats while sodium intake was kept constant and noted an inverse relationship between potassium intake and plasma renin activity. Luke et al. (63) similarly observed increases in plasma renin activity in potassium-depleted rats. Benedetti and Linas (22) studied plasma renin activity in rats with renovascular hypertension. Plasma renin activity was significantly higher in potassium-depleted rats compared with the levels noted in potassium-repleted rats. Brunner et al. (64) reported an increase in plasma renin activity in a group of normotensive and hypertensive subjects ingesting low-potassium diets. Bauer and Gaunter (61) studied 20 normal subjects maintained on a potassium intake of 0–300 mEq/day. A dose-dependent natriuretic effect and increases in plasma renin activity were noted paralleling the increase in potassium intake. Thus, high potassium intake did not alter the stimulatory effects of sodium depletion on plasma renin activity. We have investigated the effect of potassium depletion on plasma renin activity in normotensive subjects maintained on normal sodium intake (39). Nine days after ingesting diets providing either 10 mEq/day or 90 mEq/day potassium, the plasma renin activity was similar (1.9 ± 0.4 vs. 1.5 ± 0.5 ng/mL/h, P value not significant). Similarly, there was no difference in plasma renin activity between low and normal potassium intake when the sodium intake was kept low (35 mEq/day) (38). In all these studies, low-potassium diets consistently induced sodium retention (38, 39). Thus, potassium depletion modifies plasma renin activity by both a direct stimulatory effect and an indirect inhibitory effect resulting from sodium retention. The divergent responses noted in various studies represent the relative influence of these two opposing factors.

Sympathetic Nervous System. Studies done in animals and humans suggest that potassium modifies sympathetic activity, but it is not known whether these changes are causally related to changes in blood pressure (65). Fujita and Sato (66) studied the
effect of potassium supplementation on norepinephrine turnover in rats made hypertensive by the administration of DOCA and high sodium intake. Renal norepinephrine turnover was markedly accelerated in DOCA-salt rats and potassium supplementation normalized it. This normalization of norepinephrine turnover was accompanied by enhanced urinary sodium excretion and attenuation of hypertension. Thus, potassium may influence sodium excretion and blood pressure by influencing renal sympathetic activity.

Limura et al. (45) studied the effect of high (175 mEq/day) and low (25 mEq/day) potassium intake in 20 essential hypertensive subjects over 10 days. High potassium intake induced natriuresis and lowered mean arterial pressure in these subjects. Plasma norepinephrine concentrations (116 ± 9 vs. 179 ± 19 pg/mL, P < 0.005) and urinary norepinephrine excretion rates (42 ± 7 vs. 112 ± 16 µg/day, P < 0.005) were higher with high potassium intake. In contrast to these observations, Fujita and Ando (46) noted that potassium supplementation lowered plasma norepinephrine concentrations in hypertensive subjects ingesting high-sodium diets. We studied the effect of normal (90 mEq/day) and low (10 mEq/day) potassium intake on plasma and urinary catecholamines (39). The plasma norepinephrine concentrations were lower on the low-potassium diet but the values were not significantly different. Plasma epinephrine and urinary excretion rates for dopamine were similar on the two diets. The alterations in plasma norepinephrine concentrations in these studies can be explained by alterations in sodium balance.

Other Hormones. We found no alterations in plasma arginine vasopressin (39) and atrial natriuretic peptide concentrations (Krishna and Kapoor, unpublished observations) during potassium depletion. These studies do not exclude the possibility that potassium depletion modifies the vascular response to these circulating factors. Indeed, Limura et al. (45) noted that potassium supplementation lowers the pressor response to infused norepinephrine and angiotensin II in essential hypertensives. The role of other vasoactive compounds such as endothelin-derived relaxing factor, endothelin, and prostaglandins remains unstudied.

Direct Vascular Effect

Acute hypokalemia increases vascular resistance, whereas hyperkalemia exerts the opposite effect (67–71). Anderson et al. (68) infused blood into the circulation of gracilis muscle of anesthetized dogs. The plasma potassium concentration was modified by hemodialysis. An inverse relationship was noted between the potassium concentration of the perfusate and the perfusion pressure (a measure of local vascular resistance). Chen et al. (69), Haddy and Scott (70), and Brace (71) made similar observations in various experimental models. In all of these studies a marked decrease in potassium concentration was required to elicit a pressor response. In humans, increases in systemic pressure during potassium depletion are associated with minimal alterations in the serum potassium concentration (39, 40). Hence, the contribution of hypokalemia to the increase in blood pressure must be small.

More recently, Raji et al. (72) studied the effect of high potassium intake on the endothelium-dependent relaxation of aorta in hypertensive Dahl rats. Potassium supplementation lowered the blood pressure increases in rats maintained on high sodium intake. In addition, potassium supplementation enhanced the endothelium-dependent relaxations to acetylcholine in these rats (72). Thus, potassium supplementation may directly influence endothelial function.

Divalent Cation Metabolism

Calcium and magnesium have been implicated in the pathogenesis of hypertension (73, 74). An increase in potassium intake lowers urinary calcium excretion while decreasing the potassium intake has the opposite effect. Lemann et al. (75) studied the effect of potassium bicarbonate administration on divalent ion metabolism in healthy men over 12 days. Potassium bicarbonate administration reduced urinary calcium excretion by 0.9 mmol/day, whereas intestinal calcium absorption was unchanged. A decrease in urinary phosphate excretion was also observed during potassium bicarbonate administration. Magnesium chloride exerted a similar effect on calcium and phosphate metabolism, whereas sodium bicarbonate had no effect (76). It is interesting to note that potassium salts lower urinary calcium excretion while simultaneously increasing sodium excretion. The role of calcium and phosphorus in mediating potassium-induced changes in blood pressure requires further study.

Magnesium intake correlates inversely with the incidence of hypertension (73). We found no significant differences in plasma magnesium concentration and urinary magnesium excretion on low and normal potassium intakes (77). Low-potassium diets are generally low in magnesium content. It is not known whether magnesium depletion sensitizes to the hypertensive effects of potassium depletion.

SUMMARY

Potassium intake is a critical determinant of blood pressure. Epidemiologic studies suggest an inverse correlation between potassium intake and the prevalence of hypertension. These correlations are most striking in blacks. Investigations in experimental animals demonstrate a divergent response. In models
associated with sodium retention such as mineralocorticoid-induced hypertension, potassium depletion increases blood pressure. Repletion of potassium in these models induces natriuresis and lowers blood pressure. In spontaneously hypertensive rats and rats with renovascular hypertension, both potassium depletion and potassium supplementation lower blood pressure. Potassium supplementation in hypertensive subjects lowers blood pressure. Potassium depletion elevates blood pressure in normotensive subjects and hypertensive subjects ingesting normal amounts of sodium. This hypertensive response to potassium depletion is not observed in subjects ingesting low-sodium diets. Sodium retention, altered response to vasoactive hormones, direct vasoconstrictive effects of hypokalemia, and calcium depletion may all contribute to the blood pressure elevation during potassium depletion.

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REFERENCES

532.


69. Chen WT, Brace RA, Scott JB, Anderson DK.


