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Postulating the major environmental condition resulting in the expression of essential hypertension and its associated cardiovascular diseases: Dietary imprudence in daily selection of foods in respect of their potassium and sodium content resulting in oxidative stress-induced dysfunction of the vascular endothelium, vascular smooth muscle, and perivascular tissues

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A B S T R A C T

We hypothesize that the major environmental determinant of the expression of essential hypertension in America and other Westernized countries is dietary imprudence in respect of the consumption of daily combinations of foods containing suboptimal amounts of potassium and blood pressure-lowering phytochemicals, and supraphysiological amounts of sodium. We offer as premise that Americans on average consume suboptimal amounts of potassium and blood pressure-lowering phytochemicals, and physiologically excessive amounts of sodium, and that such dietary imprudence leads to essential hypertension through oxidative stress-induced vascular endothelial and smooth muscle dysfunction. Such dysfunctions restrict nitric oxide bioavailability, impairing endothelial cell-mediated relaxation of the underlying vascular smooth muscle, initiating and maintaining inappropriately increased peripheral and renal vascular resistance. The biochemical steps from oxidative stress to vascular endothelial dysfunction and its pernicious cardiovascular consequences are well established and generally accepted.

The unique aspect of our hypothesis resides in the contention that Americans' habitual consumption of foods resulting in suboptimal dietary intake of potassium and supraphysiological intake of sodium result in oxidative stress, the degree of which, we suggest, will correlate with the degree of deviation of potassium and sodium intake from optimal. Because suboptimal intakes of potassium reflect suboptimal intakes of fruits and vegetables, associated contributors to oxidative stress include suboptimal intakes of magnesium, nitrate, polyphenols, carotenoids, and other phytochemical antioxidants for which fruits and vegetables contain abundant amounts. Currently Americans consume potassium-to-sodium in molar ratios of less than or close to 1.0 and the Institute of Medicine (IOM) recommends a molar ratio of 1.2. Ancestral diets to which we are physiologically adapted range from molar ratios of 5.0 to 10.0 or higher.

Accordingly, we suggest that the average American is usually afflicted with oxidative stress-induced vascular endothelial dysfunction, and therefore the standards for normal blood pressure and pre-hypertension often reflect a degree of clinically significant hypertension. In this article, we provide support for those contentions, and indicate the findings that the hypothesis predicts.

Introduction

Medical science has identified numerous syndromes characterized in part by hypertension linked pathogenically to a single gene mutation, so called monogenic hypertension [1]. No such thing as monogenic essential hypertension exists, a contradiction in terms. Nevertheless, genes do play an important role in the pathogenesis of essential hypertension. In the general population, researchers find hundreds if not thousands of genes that have variant alleles that have a small effect on blood pressure, 1 mm Hg or less [1]. In a given person, when the number of such risk alleles increases, so does the probability that hypertension will occur, depending on environmental factors [1]. In this article we postulate that certain patterns of dietary intake constitute the most important environmental condition permitting the expression and determining the severity of hypertension in genetically susceptible persons.

Medical scientists, including physiologists and practitioners, have struggled for more than a century with the clinical problem of essential hypertension, its pathogenesis and treatment [2,3]. Less attention has been devoted to prevention. By way of a simple hypothesis we offer in this article a potential contribution for both prevention and treatment of essential hypertension.

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The hypothesis. [We] still lack a thorough understanding of the primary etiologies that lead to chronically elevated blood pressure [4].

We hypothesize that Americans, and most people in Westernized countries, habitually consume a self-selected daily diet of foods that contain exceedingly suboptimal amounts of dietary potassium and enormously supraphysiological amounts of sodium chloride [5], a dietary imprudence that causes oxidative stress, which in turn causes dysfunction of the vascular endothelium, vascular smooth muscle, and perivascular tissues. Such dysfunction ultimately results in hypertension, its associated cardiovascular diseases, and salt sensitivity of blood pressure.

Although this article will focus on dietary intake of potassium and sodium as causes of oxidative stress, we recognize that "a daily diet of foods that contain suboptimal amounts of dietary potassium" also contains suboptimal amounts of other molecular species with blood pressure regulating properties. Potassium-rich foods, predominantly fruits and vegetables, for example, also contain abundant magnesium [6], a variety of antioxidants (e.g., polyphenols, vitamins C and E) [7,8], carotenoids [9], and vasodilator precursors (e.g., nitrate) [10], any or all of which may be as important to consider.

Because fruits and vegetables are the richest dietary source of potassium, our hypothesis speaks to a greatly suboptimal intake of fruits and vegetables in regard to the most important environmental condition permitting expression and determining the severity of essential hypertension in genetically susceptible persons. Likewise, because processed foods and restaurant foods supply the major fraction (> 75%) of sodium in the average American diet [11], our hypothesis also speaks to greatly excessive intake of processed and restaurant foods in regard to the root cause of essential hypertension.

Evaluation of the hypothesis

Establishing that the foods that Americans habitually consume contain suboptimal (subphysiological [5]) amounts of potassium on average

Four lines of evidence support the argument that Americans on average suffer from a moderately severe habitual degree of potassium depletion due to a greatly suboptimal dietary potassium intake:

- The failure of Americans on average to meet the Institute of Medicine's (IOM) recommended amount of food consumption of potassium;
- The failure of the IOM's expert panel on nutrition to adopt an evolutionary perspective in determining the amount of dietary potassium consumption for which humans are genetically and physiologically adapted;
- The numerous health benefits of enriching the diet in potassium, with food or supplements.
- The deleterious effects of reducing dietary potassium intake below the current amount consumed on average.

For the 21st century, the expert panel on nutrition of the Institute of Medicine (IOM) has specified an "Adequate Intake (AI)" for potassium, namely that adults consume at least 120 mmol (mmol) [4700 mg] of potassium per day, except for those with diseases that render them potassium intolerant [12]. Americans have largely ignored that guideline or do not know about it. Table 1 shows the average values for potassium consumption by Americans (2005–2010) [13]. The values for 2013–2014 are similar, 60–80 mmol per day.

Note in Table 1 that average consumption of potassium in amounts of 60–80 mmol per day by adults falls well below the IOM recommended amount of 120 mmol per day, with American women consuming half the recommended amount on average, and American men about two-thirds. The findings do not indicate improvement in achieving "adequate intakes" in 2010–2013 over the findings reported for years 2003–2004.

Given that the IOM based their recommendation on informed analysis of the presumably best estimate of the intake rate of potassium for optimal health—but not a necessarily sufficient one for that purpose—we must conclude that Americans on average remain in a persistent state of potassium deficiency. Elderly persons may be more potassium deficient than younger persons as total body potassium declines with age [14].

The World Health Organization (WHO) recommends potassium consumption from food at the level of 90 mmol/day (3519 mg/day) and a molar ratio of potassium-to-sodium of 1.0, with the proviso that if sodium intake increases to a level that renders the ratio less than 1.0, potassium intake be increased to maintain a ratio of 1.0 [15]. Thus if sodium intake were 150 mmol/day (3450 mg/day), potassium intake should be increased to 150 mmol/day. We will argue from an evolutionary perspective, in another section below, for a much higher potassium-to-sodium molar ratio than 1.0, specifically 5.0 to 10.0 or higher, as optimal (see Table 1).

While 120 mmol of potassium consumption per day would certainly improve body potassium content by comparison with what Americans currently consume on average, no evidence indicates that 120 mmol of potassium per day provides the amount necessary for optimal physiological health. Estimates of adequate potassium intakes from an evolutionary perspective would suggest that 120 mmol per day still falls far short of optimal [16]. The lineage of our species, *Homo sapiens,* subsisted as hunters-gatherers for at least 5 million years, during which time they adapted to dietary intakes of potassium in the range of 200–400 mmol per day on average [16-18]. Because *Homo sapiens* evolved only in the last 1–2% of that 5 million year lineage, we can conclude that too little time has elapsed for the requirement for adapted potassium consumption to have changed, given that conserved core metabolic processes depend on potassium (see review by Palmer [18]). Palmer also states that "*The normal kidney has the capacity to maintain K^+ homeostasis in the setting of high dietary intake. As an example, serum K^+ levels are maintained in the normal range even when dietary K^+ intake is increased to approximately 15 g/d (586 mmol/d) for 20 days* [18].

A third line of evidence that Americans consume suboptimal amounts of potassium emerges from studies that indicate numerous health benefits when potassium intake increases, either from food sources or from supplements of potassium [18-32]. Also indicative, "*Inadequate consumption of K + combined with excessive intake of Na + contributes to the pathophysiology of various chronic diseases such as obesity, hypertension, diabetes, kidney stones, and bone disease* [18]." Aburto and colleagues conclude from their study of the literature:

> "High quality evidence shows that increased potassium intake reduces blood pressure in people with hypertension and has no adverse effect on blood lipid concentrations, catecholamine concentrations, or renal function in adults. Higher potassium intake was associated with a 24% lower risk of stroke (moderate quality evidence). These results suggest that increased potassium intake is potentially beneficial to most people without impaired renal handling of potassium for the prevention and control of elevated blood pressure and stroke [33]."

Intervention studies in which investigators have increased potassium intake demonstrate significant reductions in blood pressure and in the incidence of those cardiovascular diseases for which hypertension predicts an increased risk [18,23,25,30,33–42].

Conversely, patients with low dietary intakes of potassium have a greater risk of hypertension [43], and increased sensitivity to blood pressure increases with sodium loads [44].

Plasma potassium concentration is sensitive to reduction in potassium intake and more so as potassium intake approaches the minimum average intake for Americans [28]. The effects are exaggerated with higher sodium intakes [28].

The exaggerated anti-hypertensinogenic effect of potassium at high