Blood Pressure – Other Diet Components and Lifestyle

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In contrast to the commonly perceived role of sodium as the primary modifiable component to reduce high blood pressure, there are many other factors that significantly influence human blood pressure. Here we address dietary and lifestyle modifications that are now known to contribute to optimal blood pressure regulation.

1. INTRODUCTION

It has long been assumed that high sodium intake is a primary cause of hypertension and that restricted sodium intake will reduce and/or prevent high blood pressure. The danger in this simplification of the complex processes of both blood pressure regulation and the body's mechanisms for handling sodium is that other blood pressure-lowering strategies, many of which are equally if not more effective than sodium restriction, are neither emphasized nor implemented. There are several well-established factors other than reduced sodium intake that can significantly improve blood pressure levels, can be more easily put into practice, and are free of the adverse effects associated with sodium restriction.

High blood pressure, or hypertension, is a major risk factor for cardiovascular disease, stroke, and renal disease. Despite advances in its detection and treatment in recent years, the prevalence of hypertension continues to increase in industrialized societies. The World Health Organization currently estimates that there are 600 million people worldwide who have hypertension, and that three million deaths per year are directly attributable to this condition. Obviously, strategies that can result in lowering the incidence and prevalence of high blood pressure, and the accompanying personal and economic costs, offer multiple and extensive benefits to societies as well as to individual patients.

The pharmaceutical management of high blood pressure has greatly improved over the past two decades, but this approach is hampered by the limitations of drug efficacy, the high and life-long cost of these drug, and the inability of many people to tolerate them. In addition, side effects of many classes of antihypertensive drugs are being reported with increasing frequency. In contrast, dietary and lifestyle, or *nonpharmacologic*, measures are free of these drawbacks, involve little if any increased expense, and simultaneously confer a number of health benefits in addition to blood pressure reductions. Furthermore, unlike drugs, diet and lifestyle strategies provide possible means of disease prevention.

2. LIFESTYLE FACTORS

Of all the factors known to contribute to blood pressure regulation, body weight, or body mass index (BMI), is the strongest indicator of blood pressure in humans (3, 4). The correlation between weight and blood pressure has been observed in virtually all societies, age and ethnic

groups, and in both sexes. Obesity has consistently been shown to promote high blood pressure (5); it has been estimated that the relative risk of developing hypertension among obese adult Americans 20-45 years of age is five to six times greater than that of lean individuals (4).

Reductions in blood pressure can be achieved with as little as 4-5 kg of weight loss in a large segment of the overweight, hypertensive population (6). The blood pressure-lowering effect of even modest weight reduction has been observed in both lean (7) and obese hypertensive persons (8). Weight loss has been shown to potentiate the beneficial effects of antihypertensive medications in overweight, hypertensive patients (9), and to significantly and simultaneously improve coexisting cardiovascular risk factors including dyslipidemia and diabetes (10). As is clearly obvious, any effort aimed at lowering blood pressure or reducing the risk of developing hypertension in individual patients or across populations should begin with resolute emphasis on the achievement and maintenance of healthy body weight.

Increased physical activity is another well-established lifestyle maneuver for hypertensive persons to improve their blood pressure status as well as according the additional cardiovascular benefits of reduced cardiovascular disease risk and weight management (1). Observational studies that have assessed the effects of physical activity on cardiovascular risk have reported that a sedentary lifestyle significantly increases the risk of developing hypertension. It has been estimated that sedentary persons are at a 35% greater risk for high blood pressure than those who are physically active (11). Clinical intervention trials have also consistently demonstrated blood pressure lowering effects with increased physical activity (12).

High alcohol intake is a third lifestyle factor known to be major contributor to high blood pressure. It has also been shown to impair the efficacy of antihypertensive medications and is a known risk factor for stroke (1). Epidemiologic data indicate that alcohol consumption of three or more drinks (~30 ml ethanol each) per day is associated with both higher blood pressures and a higher prevalence of hypertension. These observational findings are supported by the clinical intervention data which demonstrate a remarkable consistency between blood pressure decreases with moderation of excessive alcohol intake in both normotensive and hypertensive persons (13).

3. DIETARY FACTORS

Sodium has generally been considered the single most influential dietary determinant of blood pressure. However, although this hypothesis has been the subject of decades of epidemiologic, laboratory, and clinical investigations, the contribution of dietary sodium to blood pressure regulation remains the most debated subject in the field of nutrition and cardiovascular health today (14).

Likely much of the controversy within the scientific community regarding the effect of sodium intake stems from the disparate results of sodium trials. Heterogeneity is a consistent feature of these studies, with individual blood pressure changes varying widely and often in opposing directions in response to modifications in sodium intake; i.e., blood pressures are reported to decrease, to increase, and to remain stable in participants within the same studies (15, 16). A clear example of heterogeneity was observed in the salt-loading study by Overlack et al. (17) in which about 18% of 163 subjects on high salt intake experienced blood pressure *increases* greater than 5 mm Hg, 16% had blood pressure *decreases* of more than 5 mm Hg, and in 66% changes were less than 5 mm Hg.

Other dietary factors known to influence blood pressure include potassium, calcium, and magnesium. Potassium intake has consistently been inversely associated with blood pressure in epidemiologic surveys (18). Similarly, meta-analyses of randomized controlled trials examining the effects of increased levels of

dietary potassium have demonstrated a significant blood pressure-lowering effect of this nutrient in persons with established hypertension (19). In a study assessing the effect of higher potassium intake from supplements or from food sources in persons with treated hypertension, it was shown that antihypertensive medication requirements were markedly reduced in those consuming naturally-occurring potassium as compared to those receiving potassium supplements (20). Also, in addition to its role in the prevention and the treatment of hypertension, dietary potassium intake has been shown to be inversely related to stroke risk, independent of its effect on blood pressure (21).

Although at less intensity than that of sodium, the influence of dietary calcium on blood pressure also continues to be a subject of controversy. Numerous epidemiologic surveys have reported an association between higher levels of dietary calcium and lower blood pressures or reduced risk of developing hypertension (22, 23). Most of the clinical trials that have examined the effect of increased calcium intake on blood pressure regulation have shown at least a minimal effect (22-25). In a meta-analysis of the appropriately designed, randomized, controlled clinical trials, Bucher et al. (24) reported significant systolic and diastolic blood pressure reductions in both hypertensive and normotensive persons. A recent update of that meta-analysis included a larger number of studies and again identified a beneficial effect of calcium (25); in addition, the latter analysis demonstrated a greater blood pressure-lowering effect when the source of the increased calcium was food products (primarily dairy) rather than supplements (tablets).

Data from a number of observational studies have indicated that there is an inverse relationship between magnesium intake and blood pressure, and that lower intake of magnesium is associated with an increased risk for hypertension (26-28). While it is clear that magnesium has a contributory role in blood pressure regulation and cardiovascular health, the limited number of clinical intervention trials that have specifically examined its effects on human hypertension have provided conflicting results. These few studies differ notably in study design, sample size, hypertension status and treatment, and administered magnesium dosage, and thus the disparate results would be expected. Furthermore, it has been postulated that supplementation at a level of 40 mmol magnesium may be required to lower blood pressure although the most commonly used levels have generally ranged from 10 to 20 (29), and also that magnesium supplementation will lower blood pressure only in the setting of magnesium deficiency (30).

A number of other dietary components have drawn investigative attention – including fats and fish oils, fiber, protein, carbohydrate, caffeine, and garlic – but none have yet been convincingly shown to play important roles in blood pressure regulation. The most prominent of these is dietary fats as there are some data suggesting an association between fat intake and blood pressure. However, these data remain inconclusive, and on the basis of available information from randomized, controlled clinical trials, the most recent report of the US NIH Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure concludes that "diets varying in total fat and proportions of saturated to unsaturated fats have had little, if any, effect on blood pressure" (1). There is currently not enough information or enough consistent information for any of the components listed above to be considered significant determinants of blood pressure regulation.

4. NUTRIENT SYNERGIES

As the above information indicates, despite decades of investigative efforts, there remain numerous unresolved questions in the area of diet and blood pressure. The discrepancies in the results of the studies, the heterogeneity of response commonly observed in clinical trials

assessing electrolytes, and therefore the lack of consensus regarding the blood pressure effects of specific nutrients have a number of possible explanations. It is likely that the anti-hypertensive effects of single nutrients are small and thus require large-scale trials for their detection. In contrast, the results of epidemiologic surveys and of clinical trials that include modifications of more than one nutrient may reflect larger, more easily detected additive effects. In addition, the observed effects of dietary interventions may be influenced by the baseline intake of the nutrient under study in individual subjects, as well as the likely possibility that nutrients provided in supplement form, as is commonly done in clinical studies, may elicit different blood pressure responses than the same nutrients from in food sources.

Considering that nutrients are not ingested in isolation, but as combined constituents of a total diet, it is not surprising that manipulations of a single nutrient would produce inconsistent and even contradictory results. If one accepts the hypothesis that micronutrients express their physiological actions through integrated pathways, then it is inconsistent to expect a uniform benefit in terms of blood pressure control by altering the intake of any one of them.

While there were earlier clues that other dietary components might be more important than the single nutrient sodium, this was clearly postulated in two articles published in the journal *Science* in the early 1980's (31, 32). Based on data acquired in the first US National Health and Nutrition Examination Survey, these analyses indicated that the principle nutritional patterns characterizing hypertensive persons are nutrient deficiencies rather than excesses. Since then, several studies have revealed relationships among nutrients, and it has become increasingly clear that nutrients function interactively both in the body and in their impact on blood pressure regulation.

5. DIETARY PATTERNS

Human diets typically comprise a variety of nutrients consumed together which act in combination to alter physiologic variables such as blood pressure; therefore, modifying the intake of any single nutrient will result in the creation of a new *dietary pattern*. For example, in a study assessing the effect on blood pressure of supplemental calcium (calcium carbonate) compared with increased calcium from food sources, Karanja and colleagues (33) reported significant simultaneous increases in the intakes of magnesium, potassium, phosphorus, riboflavin, and vitamin D in the dietary calcium group while no improvements occurred in the supplementation group. In a review of sodium restriction studies, Morris (34) found that although most did not report concurrent nutrient intake changes, those that did noted significant decreases in several essential dietary components. Improvements were often seen in energy and fat intake, but these benefits were countered by reduced intakes of calcium, potassium, fiber, and protein.

Our increased awareness of the complexity and influence of nutrient interactions has expanded research efforts in this area to include assessment of the effects of the *total diet* on blood pressure regulation. The Cardiovascular Risk Reduction Dietary Intervention Trial was a 4-year series of multicenter randomized clinical studies by the Vanguard Research Group to evaluate multiple health effects of a complete nutrition program on persons who are at higher risk of cardiovascular disease due to established hypertension, dyslipidemia, or type 2 diabetes. Free-living adult participants in this trial were provided with all their meals as a prepared (prepackaged) comprehensive food plan formulated to include vitamins, minerals, and micro- and macronutrients at the levels commonly recommended by government and voluntary health organizations for optimal health. The clinical effects of the total nutrition plan were compared to those observed with a

macronutrient-matched self-selected therapeutic diet.

The results of the first 10-week study in that trial, published in 1997, demonstrated significant improvements from both dietary plans in blood pressure, lipid levels, glycemic control, homocysteine levels, weight, overall nutrient intake, and quality of life, with greater improvements in most of these measures observed with the prepared meal plan compared to a self-selected diet (35). The second study in this series assessed the same endpoints using similar dietary interventions for 10 weeks, but reduced the amount of contact with participants to the level that would occur in actual clinical practice when dietary therapy is recommended (36). Results from this "usual care" approach were remarkably similar to the first study in this series. These studies demonstrate that, unlike modifications of the intakes of single nutrients, consumption of a nutritionally-complete and balanced diet, in which appropriate levels of nutrients are provided in combination, can improve blood pressure as well as a number of other risk factors for cardiovascular disease, including type 2 diabetes (37) and elevated homocysteine levels (38), even in persons with high-normal risk profiles.

To specifically examine the relationship between total dietary patterns and blood pressure, the US NIH initiated the multicenter, randomized, controlled Dietary Approaches to Stop Hypertension (DASH) clinical trial. This carefully designed study provided dramatic evidence of the effect and importance of the combined constituents of the overall diet on blood pressure (39). Three diets were assessed in the DASH study. The control diet was that considered to be a typical American diet, with four daily servings of fruits and vegetables and half a serving of dairy products. Potassium, calcium, and magnesium levels approximated the 25th percentile of U.S. consumption, and fiber and macronutrient levels were equivalent to the U.S. average.

The second diet was the fruits-and-vegetables diet which was similar to the control diet except that daily intake of fruits and vegetables was increased to 8.5 servings which provided levels of potassium and magnesium at approximately the 75th percentile of American consumption, and higher dietary fiber levels. The third diet was the combination diet which included 10 servings of fruits and vegetables and 2.7 servings of low-fat dairy products per day. This diet provided potassium, magnesium, and calcium at approximately the 75th percentile of consumption in the U.S. Sodium content of all diets was held constant at approximately 3 grams per day.

Blood pressure reductions were achieved with the combination diet compared to the control diet were highly significant. With the combination diet systolic pressure was reduced by 5 mmHg more and diastolic pressure by 3.0 mmHg more than with the control diet. Blood pressure reductions with the fruits-and-vegetables diet compared to the control were also highly significant, but were only about half (2.8 mmHg systolic and 1.1 mmHg diastolic) of those achieved with the combination diet. The reductions with both interventions were observed within the first 2 weeks and were sustained for the remaining 6 weeks of study.

There were no statistically significant differences in blood pressure reductions between the various population subcategories, including men, women, minority, non-minority, hypertensive, and non-hypertensive. Although there was a between-diet difference with greater reduction in minority than in non-minority persons, interaction between minority status and diet was not significant and there was no evidence of interaction between sex and diet. In both hypertensive and non-hypertensive participants, the combination diet reduced blood pressure more than the fruits-and-vegetables or the control diet. However, compared to the control diet, the combination diet achieved highly significant reductions in the normotensive

individuals for both systolic and diastolic blood pressure.

Of primary clinical significance, the blood pressure reductions observed in the hypertensive subjects on the combination compared to the control diet was 11.4 mm Hg systolic and 5.5 mm Hg diastolic blood pressure; changes in hypertensive subjects on the control diet were 0.72 mm Hg systolic and 0.28 mm Hg diastolic blood pressure. Comparison of the combination diet to the fruits-and-vegetables diet in hypertensive persons was also significantly different, with reductions of 4.1 mm Hg systolic and 2.26 mm Hg diastolic more in the combination diet than in the fruits-and-vegetables diet. The observed blood pressure reductions with the combination diet in the hypertensive subgroup were similar in magnitude to those reported in pharmacologic trials of antihypertensive treatment of mild hypertension (39).

In terms of hypertension management, it is particularly noteworthy that the DASH study accomplished these dramatic improvements despite the fact that the diet-related factors most commonly associated with blood pressure regulation – weight and sodium intake – were kept stable throughout the study and were each similar across the three diets. Thus, they were not accountable for the blood pressure changes observed in this trial; it may be that there is a protective effect on blood pressure of comprehensive nutrient intake patterns on known dietary blood pressure determinants. It is also noteworthy that no clinically significant adverse effects of these diet strategies were reported.

6. CONCLUSIONS

As described here, there are a number of lifestyle and dietary approaches to the management and prevention of hypertension, many of which have been proven to be more effective than modifying the intake level of any single nutrient. In spite of the long surmised role of sodium as the dietary nemesis of normal blood pressure control, and decades of research attempting to prove or disprove it, the subject remains controversial and recommendations based on it uncertain (14). In contrast, it is well demonstrated that the lifestyle practices of weight loss, increased physical activity, and limited alcohol intake can be effective first-line approaches to lower blood pressure and to prevent hypertension as well other chronic disorders, while simultaneously promoting overall good health.

Obviously, if the goal is to lower blood pressure the focus should be on practices that offer substantive potential to achieve that goal. Whereas the effects of individual dietary components remain the topic of continuing investigation, the benefits of improvements in weight, alcohol consumption, and exercise are unequivocal. Whether to reduce high blood pressure in one hypertensive patient or to prevent it across the population, the importance of these lifestyle modifications cannot be overstated.

Even though we have yet to define the specific impact of any given nutrient on an individual's blood pressure, advances in our understanding of dietary influences and nutrient interactions in recent years have revealed that adequate intake of multiple nutrients is critical to optimal blood pressure regulation. As dramatically demonstrated in the DASH study, diets that contain the full constellation of required nutrients are the most effective means of achieving appropriate blood pressure levels in both normotensive and hypertensive persons. Rather than instituting population-wide recommendations for specific intake levels of any one nutrient to reduce hypertension, emphasis should be on factors that have been clearly demonstrated to offer blood pressure benefits – appropriate lifestyle practices and the adequate intake of all essential nutrients through nutritionally-balanced and complete diets.

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