The DASH Diet: Implications for People With Diabetes

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ABSTRACT

Hypertension is twice as frequent in patients with diabetes compared to the general population. The past decade has rekindled the debate surrounding the optimal dietary prescription, including macronutrient composition, for the treatment of diabetes and its associated risk factors. In 1997, the Dietary Approaches to Stop Hypertension (DASH) trial, a multicentre, randomized, feeding study, marked an important advance in our understanding of the effects of overall dietary patterns on blood pressure (BP). An impressive reduction of 11.4 and 5.5 mm Hg for systolic blood pressure (SBP) and diastolic blood pressure (DBP), respectively, was seen in patients with hypertension who consumed the DASH diet (which is rich in fruits, vegetables and low-fat dairy foods) compared to the control diet. Widespread adoption and promotion of the DASH diet has the potential to contribute to meaningful reductions in BP, improve concomitant cardiovascular risk factors in persons with diabetes and ultimately improve their health and quality of life.

RÉSUMÉ

L'hypertension est deux fois plus fréquente chez les patients atteints de diabète que dans la population générale. Au cours des dix dernières années, le débat a repris au sujet du régime alimentaire optimal, y compris la composition en éléments minéraux, pour le traitement du diabète et des facteurs de risque associés. En 1997, l'essai DASH (*Dietary Approaches to Stop Hypertension*), un essai multicentrique portant sur le régime alimentaire et comportant une répartition aléatoire, a contribué à améliorer considérablement notre compréhension des effets des habitudes alimentaires sur la pression sanguine. Au cours de cet essai, il y a eu des baisses respectives impressionnantes de la pression systolique et de la pression diastolique de 11,4 et de 5,5 mm Hg chez les hypertendus qui suivaient la diète DASH (riche en fruits, légumes et produits laitiers à faible teneur en matière grasse) plutôt qu'une diète témoin. La promotion de la diète DASH et son adoption par une forte proportion de personnes pourraient contribuer à réduire concrètement la pression sanguine, à atténuer les facteurs de risque de maladie cardio-vasculaire chez les personnes atteintes de diabète et, en bout de ligne, à améliorer la santé et la qualité de vie.

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INTRODUCTION

Cardiovascular disease (CVD) is a major cause of morbidity and mortality in persons with diabetes (1). Clustering of metabolic risk factors is common in patients with diabetes and includes insulin resistance, obesity and dyslipidemia (2). Hypertension is another major contributing factor to the higher prevalence of CVD in diabetes, is twice as frequent in patients with diabetes compared to the general population (3) and is a contributing factor in an estimated 30 to 75% of diabetes complications (4). The Canadian Diabetes Association's (CDA's) 1998 Clinical Practice Guidelines for the Management of Diabetes in Canada advocate for tighter metabolic control in most people with diabetes and increased attention to lifestyle, adjustments in diet and physical activity (5). The evidence is conclusive that management of hypertension significantly reduces the incidence of stroke, heart failure and progression of complications of diabetes (6).

Lifestyle modifications are an integral part of the management of hypertension. Common behavioural prescriptions for the prevention and treatment of high blood pressure (BP) include achieving an optimum body weight, limiting sodium intake and moderating alcohol intake (7,8). The past decade has rekindled the debate surrounding the optimal dietary prescription, including macronutrient composition, for the treatment of diabetes and associated risk factors. Due to the difficulty in ascribing a causative role to the effects of single dietary components in improving health outcomes, it is advantageous to examine overall dietary patterns and their influence on defined health endpoints.

CURRENT DIETARY RECOMMENDATIONS FOR HYPERTENSION

Previously, the 2 most common dietary prescriptions for hypertension were weight loss and sodium restriction. The Trials of Hypertension Prevention, Phase I (TOHP I) assessed the efficacy of weight loss and sodium restriction in preventing progression to hypertension (9). Data collected for 7 years following the TOHP I demonstrated that 40.5% of subjects in the control group progressed to hypertension, while only 18.9% of subjects in the active weight loss group progressed to hypertension ($p=0.02$) (9). In the sodium-restricted group, 22.4% of subjects developed hypertension, while 32.9% of control subjects developed hypertension ($p=0.19$) (9).

Other studies have shown the beneficial effect of sodium restriction on BP in clinical settings, yet the highly restrictive nature of these diets continues to raise challenges with compliance. In addition, not all individuals are sodium sensitive and therefore do not achieve a meaningful BP-lowering benefit from a sodium-restricted diet. In addition to sodium-restricted diets, several other diets and dietary components have received attention in relation to the prevention and control of hypertension.

VEGETARIAN DIETS, MINERALS AND PROTEIN

Individuals who consume a vegetarian diet tend to have lower BP than do non-vegetarians (10). Sacks and colleagues described a downward shift in the population mean of both systolic blood pressure (SBP) and diastolic blood pressure (DBP) in vegetarians compared to non-vegetarians (11). It was suggested that nutrients eaten in greater amounts in vegetarian vs. non-vegetarian diets lower BP (10). As a result, several components of vegetarian diets have been examined in greater depth to elucidate the key BP regulating nutrients.

In observational studies, generally positive results link the intake of calcium, magnesium, potassium and dietary fibre to a reduction in the relative risk of hypertension (12). Mineral intake appears particularly important in relation to sodium sensitivity. Many studies show that a significant portion of BP variability in response to sodium can be linked to the adequacy of mineral intake (13). Observational data suggest that adequate intake of calcium, potassium and magnesium simultaneously with a diet high in sodium is not associated with increased arterial pressure (13). In clinical trials, however, where isolated calcium, potassium and magnesium have been supplemented into the diet, the results have been less consistent and do not tend to show an equivalent BP-lowering effect (12,14). A meta-analysis of potassium supplementation did show a BP-lowering effect, but randomized, well-controlled trials showed minimal effect (15). A similar meta-analysis for calcium supplementation showed a small reduction in SBP, but not DBP (16). While no meta-analyses for magnesium have been conducted, no overall BP-lowering effect has been detected in several smaller trials (17,18). Initial micronutrient status of study participants may partially account for this discrepancy. Clearly, the interaction between adequacy of mineral intake and protection against sodium sensitivity is important and suggests that overall dietary patterns that meet or exceed recommended levels for calcium, potassium and magnesium may be beneficial in patients with hypertension.

Epidemiological studies of stroke in Japanese populations suggest that a diet high in dietary protein is protective against hypertension (19). The Multiple Risk Factor Intervention Trial (MRFIT) demonstrated that higher levels of dietary protein in the diet (22 vs. 12% of total kilocalories [kcal, 1 kcal=1 Cal]) were associated with an estimated lowering of 1.0 mm Hg for SBP and 1.1 mm Hg for DBP (20). The results of the International Study of Salt and Blood Pressure (INTERSALT), in which BP was assessed in relation to markers of dietary protein in 24-hour urine collections, also suggest that moderately increased levels of protein in the diet have a favourable influence on BP.

Other epidemiological studies suggest that populations that consume large amounts of fish and seafood, such as Greenland Eskimos, have lower rates of CVD (21). Dietary fish oils are high in omega-3 fatty acids (O3FA). A meta-analysis reported that supplementation with O3FA (more than 3 g/day) led to clinically relevant BP reductions in individuals with untreated hypertension (22). While large amounts of O3FA may impair glucose tolerance in persons with type 2 diabetes (23), an Australian trial has demonstrated that the addition of fish to a weight-control diet improves glucose, insulin and lipid metabolism in overweight, hypertensive subjects (24). Meals incorporating fish that are rich in O3FA may effectively reduce the risk of CVD.

The reasons for the often-inconsistent results seen between observational studies and clinical trials that supplement single nutrients may be several-fold. With increasing analytical capabilities, our knowledge of the biochemical structure-function relationships of the myriad of chemicals that occur naturally in food is increasing (25). It is likely that numerous nutrients in foods, interacting with other dietary components, may reduce BP to a greater extent than specific isolated nutrients supplemented into the diet. It is also plausible that individual nutrients may have very minor BP-lowering effects. In combination with other nutrients with similar minor effects, the cumulative effect of these nutrients may then be sufficient for detection in human trials. To address some of these issues, the Dietary Approaches to Stop Hypertension (DASH) trial was designed to test the effects of dietary patterns on BP (26).

THE DASH TRIAL

The DASH trial was a multicentre, randomized, feeding study that evaluated the combined effects of nutrients that occur together in food (27). The study involved 459 adults with SBP <160 mm Hg and DBP of 80 to 95 mm Hg. For 3 weeks, all subjects consumed a control diet. Subjects were then randomly assigned to receive one of the following 3 diets for 8 weeks: a control diet similar to the average diet in the United States (US); a diet rich in fruits and vegetables; or a "combination" diet rich in fruits, vegetables and low-fat dairy products (Table 1). Body weight and sodium intake was maintained at constant levels throughout the trial.

The results of the trial were an impressive reduction in BP with the combination diet (now referred to as the DASH diet). The DASH diet reduced SBP and DBP by 5.5 and 3.0 mm Hg, respectively, more than did the control diet (Figure 1) (27). The fruits-and-vegetables diet produced results midway between the DASH and control diets, with a reduction of 2.8 and 1.1 mm Hg for SBP and DBP, respectively. These results suggest that some components in the fruits-and-vegetables diet reduce BP, but the additional components included in the DASH diet reduced it even further. An even greater reduction in BP was observed in subjects with mild hypertension (SBP ≥140 mm Hg; DBP ≥90 mm Hg). The DASH diet reduced SBP and DBP by 11.4 and 5.5 mm Hg, respectively, more than did the control diet (Figure 2). These reductions are comparable to those observed in single drug trials for mild hypertension (28-32).

Evidence suggests that the effects of diet on BP may be influenced by demographic characteristics such as race, age and sex (33). In a subgroup analysis, the DASH diet lowered SBP more substantially in African Americans (6.8 mm Hg) than in non-Hispanic Caucasians (3.0 mm Hg). In African Americans with hypertension, the effects were an impressive 13.2 and 6.1 mm Hg reduction in SBP and DBP, respectively. The background diets of the DASH participants may explain some of the impressive reductions that were documented. Decreased potassium and calcium intakes are 2 of the factors postulated to explain a higher prevalence of hypertension in the African American population (34). In pre-enrollment diet analysis of DASH participants, African Americans reported lower intakes of dairy products, calcium and magnesium than Caucasians (35). Previous work by Sacks and colleagues (14) showed that patients with higher pre-study intakes of calcium and potassium experienced no significant changes in BP with combinations of these mineral supplements. Therefore, the background diet of individuals may influence response to the DASH diet, with those with the poorest intake benefitting the most.

Table 1. Diet composition* (adapted from reference 26)

Nutrients	*Control diet*	*Fruits-and-vegetables diet*	*DASH diet*
Fat (% of total kcal)	35.7	35.7	25.6
Saturated	14.1	12.7	7.0
Monounsaturated	12.4	13.9	9.9
Polyunsaturated	6.2	7.3	6.8
Carbohydrates (% of total kcal)	50.5	49.2	56.5
Protein (% of total kcal)	13.8	15.1	17.9
Cholesterol (mg/day)	233	184	151
Fibre (g/day)†	9	31	31
Potassium (mg/day)	1752	4101	4415
Magnesium (mg/day)	176	423	480
Calcium (mg/day)	443	534	1265
Sodium (mg/day)	3028	2816	2859

*Diet composition values derived from chemical analyses of menus for 2100 kcal
†Based on nutrient targets. Chemical analyses not available

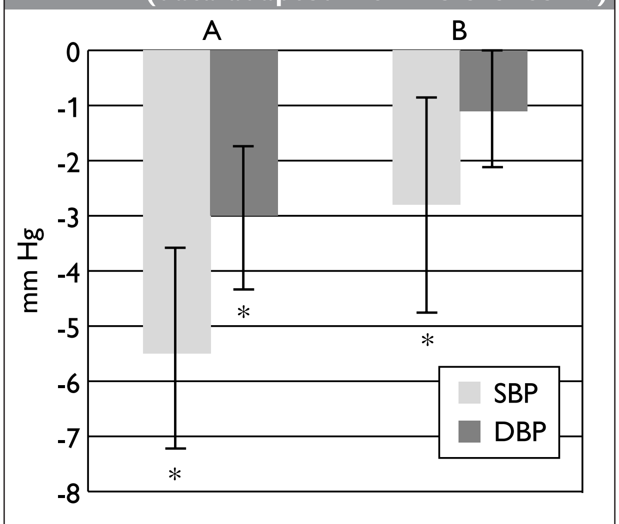
The broad applicability of the DASH diet to the general public is supported by evidence of the BP-lowering effects of the diet across multiple subgroups defined by sex, age, body mass index (BMI) and socioeconomic status (33). The distinctive benefit to African Americans is especially promising, as this group suffers a disproportionate burden of morbidity and mortality from hypertension (36). Individuals with type 2 diabetes also suffer an increased burden of morbidity and mortality due to hypertension (3). It appears reasonable to anticipate that a similar BP-lowering benefit with the DASH diet would be recognized in this high-risk group.

THE DASH-SODIUM TRIAL

The diets in the original DASH trial were formulated to contain equivalent sodium levels (27). A follow-up trial performed by the DASH-Sodium Collaborative Research Group examined the effect of different levels of dietary sodium intake in conjunction with the DASH diet (37). Within the 3 assigned diets, participants consumed foods with high, intermediate or low levels of sodium for 30 days each, in random order. The results, shown in Figure 3, confirmed the BP-lowering effects of the original DASH trial and demonstrated a further reduction in BP due to reduced sodium intake. There was a significant difference in SBP between the high-sodium and low-sodium phases of the control diet (mean: -6.7 mm Hg; 95% confidence interval [CI], -5.4 to -8.0; p<0.001) and the DASH diet (mean: -3.0 mm Hg; 95% CI, -1.7 to -4.3; p<0.001), and between the high-sodium phase of the control diet and the low-sodium phase of the DASH diet (mean: -8.9 mm Hg; 95% CI, -6.7 to -11.1; p<0.001) (37). There was also a significant difference in DBP between the high-sodium and low-sodium phases of the control diet (mean: -3.5 mm Hg; 95% CI, -2.6 to -4.3; p<0.001) and of the DASH diet (mean: -1.6 mm Hg; 95% CI, -0.8 to -2.5; p<0.001), and between the high-sodium phase of the control diet and the low-sodium phase of the DASH diet (mean: -4.5 mm Hg; 95% CI, -3.1 to -5.9; p<0.001).

The DASH diet was associated with a significantly lower SBP at each sodium level. The greatest reduction in SBP was observed between the control diet with high sodium and the DASH diet with low sodium in participants without

Figure 1. Comparison of mean changes in BP between diets in all subjects (data adapted from reference 27)

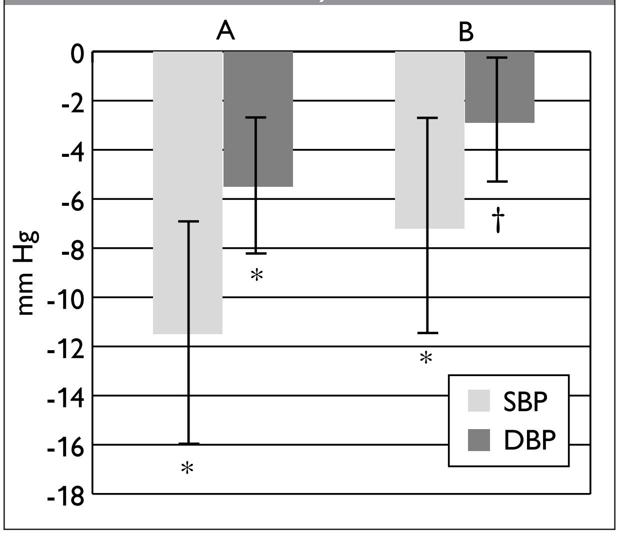


A: Change in combination group minus change in control group
B: Change in fruits-and-vegetables group minus control group

A p value of <0.025 was considered to indicate statistical significance
*p<0.001
Error bars denote the 97.5% CI

BP = blood pressure
DBP = diastolic blood pressure
SBP = systolic blood pressure

Figure 2. Comparison of mean changes in BP between diets in hypertensive subjects (data adapted from reference 27)



A: Change in combination group minus change in control group
B: Change in fruits-and-vegetables group minus control group

A p value of <0.025 was considered to indicate statistical significance
*p<0.001
†p<0.01
Error bars denote the 97.5% CI
Hypertension was defined as baseline SBP ≥140 mm Hg or DBP ≥90 mm Hg
Nonhypertension was defined as baseline SBP <140 mm Hg and DBP <90 mm Hg

BP = blood pressure
DBP = diastolic blood pressure
SBP = systolic blood pressure

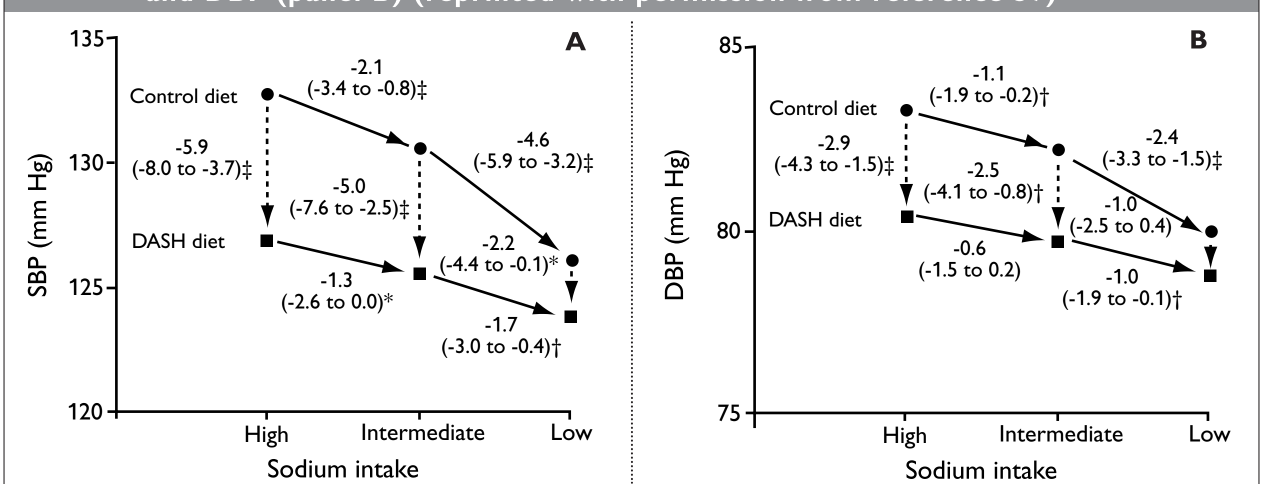
hypertension (7.1 mm Hg) and in participants with hypertention (11.5 mm Hg) (37).

In Canada, current guidelines for lifestyle modification to prevent and control hypertension include a recommendation to choose foods low in sodium and to minimize the use of sodium at the table and during cooking (7). The average sodium intake in the US is approximately 150 mmol/day, equivalent to approximately 3.5 g of sodium or 8.7 g of sodium chloride (37). In the DASH-Sodium trial, the 3 levels of sodium intake were high (150 mmol), intermediate (100 mmol) and low (50 mmol). A target of 100 mmol/day reflects the upper limit of current national recommendation (38). The positive results of the trial provide important evidence to support the advised reduction of sodium intake as a means of lowering BP in persons with hypertension as well as those without hypertension, a previously controversial issue. The results of the trial also demonstrated that BP could be lowered in those who consumed either a typical North American diet or the DASH diet. The overall message derived from the DASH-Sodium trial is that the combined effects of low sodium intake and the DASH diet reduce BP more than either intervention alone. As with many dietary recommendations, the greatest consideration must be given to the sustainability of the dietary intervention or, in this case, the capacity for people to achieve lower sodium intakes. Sodium restriction is particularly challenging, as any long-lasting dietary modification is highly dependent on the food processing industry, and enhanced advocacy is likely required to increase the availability of low-sodium processed food choices for the consumer.

DASH DIET FOR DIABETES

It has been suggested that the DASH diet is widely applicable to the general population (27,37). Individuals with diabetes were among the subjects involved in the DASH trials. However, individuals with uncontrolled diabetes or diabetes requiring insulin were excluded from participation in the studies. Therefore, although the DASH diet has not been specifically examined in subjects with diabetes, the efficacy of the diet may still be relevant for this subgroup. The significant BP-lowering effects observed with the DASH diet across all subgroups defined by sex, age, BMI and socioeconomic status suggest a broad applicability for this intervention (33). In addition, the even greater reductions in BP realized in hypertensive subjects, who would comprise a large portion of the population with diabetes, suggest that this intervention may be especially beneficial. The fact that the diet appears to work best for groups at highest risk and those with the poorest dietary intake is encouraging (39). In light of this, the most recent recommendation for BP goals in persons with diabetes is 130/80 mm Hg (40). In order to achieve this standard, it is

Figure 3. The effect of reduced sodium intake and the DASH diet on SBP (panel A) and DBP (panel B) (reprinted with permission from reference 37)



Mean SBP and DBP are shown for the high-sodium control diet

Mean changes in BP are shown for various sodium levels (solid lines), and mean differences in BP between the 2 diets at each level of sodium intake are shown

Unidirectional arrows are used for simplicity, although the order in which participants were given the sodium levels was random, with a crossover design

Numbers next to the dotted lines connecting the data points are the mean changes in BP

The 95% CIs are given in parentheses

*($p<0.05$), †($p<0.001$) and ‡($p<0.001$) indicate significant differences in BP between groups or between dietary sodium categories

BP = blood pressure

DBP = diastolic blood pressure

SBP = systolic blood pressure

clearly advantageous to have as many tools available as possible to help patients achieve this goal. Many patients find current dietary guidelines restrictive and compliance is often difficult to maintain over extended periods. For this reason, the DASH diet, which includes readily available, affordable foods and was well accepted by study participants, may improve compliance (41,42).

The DASH diet is also consistent with other dietary recommendations set forth by international health agencies. The American Heart Association (AHA) Dietary Guidelines now include the DASH diet as a specific recommendation to achieve and maintain normal BP (8). The fat content of the DASH diet (6% of energy from saturated fat) is consistent with the saturated fat intake (<10% of energy) advocated by the AHA (8). Dietary recommendations to prevent osteoporosis are similar to the dairy content and calcium content (1200 mg/day/2100 kcal) of the DASH diet (43). The fruit and vegetable content of the DASH diet is also consistent with current Canadian dietary guidelines of 5 to 10 servings per day to prevent cancer and heart disease (44). Finally, the CDA's Guidelines for Nutritional Management of Diabetes Mellitus (45) are in keeping with the overall healthy eating patterns that characterize the DASH diet.

The effects of the DASH diet on health outcomes beyond BP and in other chronic diseases such as diabetes, cancer and osteoporosis remain to be examined, but appear promising. The first of these investigations has been reported in a recent study examining the effects of the DASH diet on blood lipids. The DASH diet resulted in significantly lower total low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) (46). These findings suggest that the DASH diet is likely to reduce the risk of coronary heart disease (CHD), but the reduction in HDL-C and its possible opposing effect on heart health need further study.

One final consideration in the use of the DASH diet in persons with diabetes is its effect on glycemic control. There are reports that diets high in carbohydrates may be detrimental to glycemic control in persons with diabetes (47,48). Compared to the control and fruits-and-vegetables diets that contained 48% of total energy from carbohydrates, the DASH diet provided 55% of total energy from carbohydrates. The DASH diet, however, also provided 31 g/day of dietary fibre, which has generally been associated with improvements in glycemic control for patients with type 2 diabetes (49,50). Several epidemiological studies have also linked consumption of fibre-rich foods to a reduced risk of development of type 2 diabetes (51). In addition to fibre content, the increased contribution of dietary protein in the DASH diet (18 vs. 15% of total energy in the control and fruits-and-vegetables diets) is also noteworthy. Gutierrez and colleagues observed improved glycemic control in subjects with type 2 diabetes who consumed a high-protein diet (45% of total energy) (52). Studies examining weight loss have also demonstrated that weight loss with a high-protein diet (25 to 45% of total energy) is greater than that with a low-protein diet (≈12% of total energy) in obese, hyperinsulinemic subjects and subjects with type 2 diabetes (53-55). While weight loss is clearly a goal for most patients with type 2 diabetes, the implications of achieving this loss with protein-rich diets remains controversial with regard to kidney function and risk of breast and colon cancers. While 1 report suggests that moderate changes in dietary protein intake cause positive adaptive changes in renal size and function (56), the health benefits of weight loss must be weighed against other health concerns. It must also be clarified that the DASH diet contains 18% of total dietary energy from protein, only 3% more than the control and fruits-and-vegetables diets. This higher protein content may help to increase compliance without precipitating adverse health consequences.

PRACTICAL CONSIDERATIONS

In the fruits-and-vegetables and the DASH diets, subjects consumed 8 to 10 servings of fruits and vegetables per day (27). The current average consumption is 4.3 servings per day, and national guidelines advocate at least 5 to 10 servings per day. The DASH diet provided 2.7 servings of low-fat dairy products per day (27). The average consumption of dairy products currently is 1.5 servings per day, and the dietary guidelines suggest 2 to 3 servings per day. Clearly, the patient who is advised to follow the DASH diet will require specific instruction on how to incorporate into their daily meal plan the servings of fruits and vegetables and low-fat dairy products that resulted in the BP-lowering effects seen in the DASH trial. In addition, the DASH diet included whole grains, nuts, fish, poultry and reduced levels of red meats, sweets and sugar-containing beverages.

Even for highly motivated patients, the multiple dietary modifications required to achieve an intake similar to the DASH diet can be overwhelming. Windhauser and colleagues (42) examined the translation of the DASH diet from research to practice, and suggested that motivational interviewing be used to help patients examine and resolve ambivalence about behaviour change, to reduce resistance and to enhance long-term adherence (42). Furthermore, patients need to be encouraged to select dietary modifications that will fit their lifestyle and become permanent healthy eating behaviours. For some, the changes may need to be small and gradual, while for those who display greater motivation, substantial modifications may be made more quickly. Kolasa describes a generally positive adaptation of the DASH diet in the primary care setting but notes that the challenge of incorporating this intervention into primary care by more practitioners remains (57).

Several excellent resources are available that may aid in the implementation of the DASH diet. An educational booklet with diet tips, menus and recipes provides details about the DASH diet (58), a detailed description of the foods included in the DASH study menus and their nutrient contents has been published (59), and the National Heart, Lung, and Blood Institute also provides useful information for dietitians and patients about the DASH diet and lowering BP (60).

GENETIC INFLUENCES ON THE RESPONSE TO DIETARY INTERVENTION

A final comment must be made with regard to the interaction of genetics and environment and the contribution of these 2 factors to the pathology and treatment of hypertension. Twin and family studies document a significant heritable component in BP levels and hypertension (61,62). Sodium sensitivity, the response in BP to changes in sodium and water homeostasis, is found in 73% of hypertensive African Americans and contains a heritable component (63). African Americans suffer a disproportionate burden of morbidity and mortality from hypertension (64), and a concerted effort is being made to understand the genetic determinants of hypertension and to identify candidate phenotypes (65). Recent evidence also suggests that a significant gene-nutrient interaction occurs at the peroxisome proliferator-activated receptor (PPAR) -gamma locus. PPAR-gamma is important in regulating adipose tissue growth, insulin resistance and BP (66,67). Work by Luan and colleagues (68) describes a situation in which BMI is dependent on both the dietary polyunsaturated to saturated ratio (P:S) and the presence of a genetic polymorphism in the PPAR-gamma locus. Perhaps the best evidence for a gene-diet interaction is found in the angiotensinogen genotype. Angiotensinogen, a substrate for the renin-angiotensin system, plays a significant role in BP regulation. Hypertensive persons have higher circulating angiotensinogen plasma levels, and this generally correlates with BP (69,70). A DASH substudy demonstrated an association between a polymorphism of the angiotensinogen gene and response to the DASH diet (71). BP response to the DASH diet was greatest in individuals with the AA genotype and lowest in those with the GG genotype (see reference 71 for a complete description of the genotypes). These examples serve simply to make a case for the interaction of multiple genes and the environment and for the individual responsiveness that is likely to occur with any nutritional intervention. With our dramatically increasing understanding of the human genome, it is perhaps likely that in the future genomic blueprints could be tailored to dietary recommendations that are most likely to result in the desired health outcomes.

CONCLUSION

It is clear that the risk of CVD increases throughout the normotensive BP range. It has been suggested that lowering the median BP of the population by 2 mm Hg could be more effective in reducing the rate of CVD than medically treating individual patients who have DBP >95 mm Hg (72). The latest estimates suggest that 22% of Canadian adults have hypertension. The incidence increases with age and most elderly Canadians have high BP (7). Persons with diabetes have approximately twice the incidence of hypertension as persons without diabetes. Given that the greatest number of hypertensive individuals have mild or Stage I hypertension, the DASH diet should be viewed as an important lifestyle intervention aimed at controlling hypertension and potentially reducing the need for antihypertensive medication. The DASH diet is consistent with all other public health recommendations currently advocated for reduction of heart disease, diabetes, cancer and osteoporosis (73). In the landmark study by Tuomilehto and colleagues (74), the collective lifestyle changes of reducing weight, total intake of fat and saturated fat, and increasing intake of fibre and physical activity reduced the risk of diabetes by 58%. The reduction in the incidence of diabetes was directly associated with changes in lifestyle (74). The DASH diet is an important addition to nutritional strategies available for lifestyle interventions aimed at the prevention and treatment of hypertension and ultimately the improved quality of life for persons with diabetes.

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REFERENCES

1. Sowers JR, Epstein M, Frohlich ED. Diabetes, hypertension, and cardiovascular disease: an update. *Hypertension*. 2001;37:1053-1059.
2. Timar O, Sestier F, Levy E. Metabolic syndrome X: a review. *Can J Cardiol*. 2000;16:779-789.
3. Wang SL, Head J, Stevens L, Fuller JH. Excess mortality and its relation to hypertension and proteinuria in diabetic patients. The World Health Organization multinational study of vascular disease in diabetes. *Diabetes Care*. 1996;19:305-312.
4. Krolewski AS, Kosinski EJ, Warram JH, et al. Magnitude and determinants of coronary artery disease in juvenile-onset, insulin-dependent diabetes mellitus. *Am J Cardiol*. 1987;59:750-755.
5. Meltzer S, Leiter L, Daneman D, et al. 1998 clinical practice guidelines for the management of diabetes in Canada. *CMAJ*. 1998;159(suppl 8):S1-S29.
6. UK Prospective Diabetes Study Group. Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 38. *BMJ*. 1998;317:703-713.
7. Leiter LA, Abbott D, Campbell NR, et al. Lifestyle modifications to prevent and control hypertension. 2. Recommendations on obesity and weight loss. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. *CMAJ*. 1999;160(suppl 9):S7-S12.
8. Krauss RM, Eckel RH, Howard B, et al. AHA dietary guidelines: revision 2000: a statement for healthcare professionals from the Nutrition Committee of the American Heart Association. *Stroke*. 2000;31:2751-2766.
9. Trials of Hypertension Prevention Collaborative Research Group. The effects of nonpharmacologic interventions on

blood pressure of persons with high normal levels. Results of the Trials of Hypertension Prevention, Phase I. *JAMA*. 1992; 267:1213-1220.
10. Sacks FM, Kass EH. Low blood pressure in vegetarians: effects of specific foods and nutrients. *Am J Clin Nutr*. 1988; 48(suppl 3):795-800.
11. Sacks FM, Rosner B, Kass EH. Blood pressure in vegetarians. *Am J Epidemiol*. 1974;100:390-398.
12. Hermansen K. Diet, blood pressure and hypertension. *Br J Nutr*. 2000;83(suppl 1):S113-S119.
13. McCarron DA. Role of adequate dietary calcium intake in the prevention and management of salt-sensitive hypertension. *Am J Clin Nutr*. 1997;65(suppl 2):712S-716S.
14. Sacks FM, Brown LE, Appel L, et al. Combinations of potassium, calcium, and magnesium supplements in hypertension. *Hypertension*. 1995;26:950-956.
15. Cappuccio FP, MacGregor GA. Does potassium supplementation lower blood pressure? A meta-analysis of published trials. *J Hypertens*. 1991;9:465-473.
16. Cutler JA, Brittain E. Calcium and blood pressure. An epidemiologic perspective. *Am J Hypertens*. 1990;3:137S-146S.
17. Dyckner T, Wester PO. Effect of magnesium on blood pressure. *BMJ*. 1983;286:1847-1849.
18. Cappuccio FP, Markandu ND, Beynon GW, et al. Lack of effect of oral magnesium on high blood pressure: a double blind study. *BMJ*. 1985;291:235-238.
19. Kagan A, Popper JS, Rhoads GG, Yano K. Dietary and other risk factors for stroke in Hawaiian Japanese men. *Stroke.* 1985;16:390-396.
20. Stamler J, Caggiula A, Grandits GA, et al. Relationship to blood pressure of combinations of dietary macronutrients. Findings of the Multiple Risk Factor Intervention Trial (MRFIT). *Circulation*. 1996;94:2417-2423.
21. Holub BJ. Dietary fish oils containing eicosapentaenoic acid and the prevention of atherosclerosis and thrombosis. *CMAJ*. 1988;139:377-381.
22. Appel LJ, Miller ER 3rd, Seidler AJ, Whelton PK. Does supplementation of diet with 'fish oil' reduce blood pressure? A meta-analysis of controlled clinical trials. *Arch Intern Med*. 1993;153:1429-1438.
23. Malasanos TH, Stacpoole PW. Biological effects of omega-3 fatty acids in diabetes mellitus. *Diabetes Care*. 1991;14:1160-1179.
24. Mori TA, Bao DQ, Burke V, et al. Dietary fish as a major component of a weight-loss diet: effect on serum lipids, glucose, and insulin metabolism in overweight hypertensive subjects. *Am J Clin Nutr*. 1999;70:817-825.
25. Sheehy T, Morrissey PA. Functional foods: prospects and perspectives. In: Henry CJK, Heppell NJ, eds. *Nutritional Aspects of Food Processing*. Gaithersburg, MD: Aspen Publishers; 1998:45-65.
26. Sacks FM, Obarzanek E, Windhauser MM, et al. Rationale and design of the Dietary Approaches to Stop Hypertension trial (DASH). A multicenter controlled-feeding study of dietary patterns to lower blood pressure. *Ann Epidemiol*. 1995;5:108-118.
27. Appel LJ, Moore TJ, Obarzanek E, et al. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. *N Engl J Med*. 1997;336:1117-1124.
28. The Treatment of Mild Hypertension Research Group. The treatment of mild hypertension study. A randomized, placebo-controlled trial of a nutritional-hygienic regimen along with various drug monotherapies. *Arch Intern Med*. 1991;151:1413-1423.
29. Materson BJ, Reda DJ, Cushman WC, et al. Single-drug therapy for hypertension in men. A comparison of six antihypertensive agents with placebo. The Department of Veterans Affairs Cooperative Study Group on Antihypertensive Agents. *N Engl J Med*. 1993;328:914-921.
30. Lacourciere Y, Tytus R, O'Keefe D, et al. Efficacy and tolerability of a fixed-dose combination of telmisartan plus hydrochlorothiazide in patients uncontrolled with telmisartan monotherapy. *J Hum Hypertens*. 2001;15:763-770.
31. Flack JM, Saunders E, Gradman A, et al. Antihypertensive efficacy and safety of losartan alone and in combination with hydrochlorothiazide in adult African Americans with mild to moderate hypertension. *Clin Ther*. 2001;23:1193-1208.
32. Deary AJ, Schumann AL, Murfet H, et al. Double-blind, placebo-controlled crossover comparison of five classes of antihypertensive drugs. *J Hypertens*. 2002;20:771-777.
33. Svetkey LP, Simons-Morton DG, Vollmer WM, et al. Effects of dietary patterns on blood pressure: subgroup analysis of the Dietary Approaches to Stop Hypertension (DASH) randomized clinical trial. *Arch Intern Med*. 1999;159:285-293.
34. Richardson AD, Piepho RW. Effect of race on hypertension and antihypertensive therapy. *Int J Clin Pharmacol Ther*. 2000;38:75-79.
35. Karanja NM, McCullough M, Kumanyika S, et al. Pre-enrollment diets of Dietary Approaches to Stop Hypertension trial participants. DASH Collaborative Research Group. *J Am Diet Assoc*. 1999;99(suppl 8):S28-S34.
36. Weinberger MH, Miller JZ, Luft FC, et al. Definitions and characteristics of sodium sensitivity and blood pressure resistance. *Hypertension*. 1986;8:II127-II134.
37. Sacks FM, Svetkey LP, Vollmer WM, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. *N Engl J Med*. 2001;344:3-10.
38. The sixth report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. *Arch Intern Med*. 1997;157:2413-2446.
39. Tucker K. Dietary patterns and blood pressure in African Americans. *Nutr Rev*. 1999;57:356-358.
40. Bakris GL. A practical approach to achieving recommended blood pressure goals in diabetic patients. *Arch Intern Med*. 2001;161:2661-2667.
41. Conlin PR. The Dietary Approaches to Stop Hypertension (DASH) clinical trial: implications for lifestyle modifications in the treatment of hypertensive patients. *Cardiol Rev*. 1999;7:284-288.
42. Windhauser MM, Ernst DB, Karanja NM, et al. Translating the Dietary Approaches to Stop Hypertension diet from research

to practice: dietary and behavior change techniques. DASH Collaborative Research Group. *J Am Diet Assoc*. 1999; 99(suppl 8):S90-S95.

43. Food and Nutrition Board. Institute of Medicine. *Dietary Reference Intakes. Applications in Dietary Assessment*. Washington, DC: National Academy Press; 2001.
44. Birkett NJ. Intake of fruits and vegetables in smokers. *Public Health Nutr*. 1999;2:217-222.
45. Wolever T, Barbeau M-C, Charron S, et al. Guidelines for the nutritional management of diabetes mellitus in the new millennium: a position statement by the Canadian Diabetes Association. *Can J Diabetes Care*. 1999;23(3):56-69.
46. Obarzanek E, Sacks FM, Vollmer WM, et al. Effects of blood lipids of a blood pressure-lowering diet: the Dietary Approaches to Stop Hypertension (DASH) trial. *Am J Clin Nutr*. 2001;74:80-89.
47. Garg A, Grundy SM, Koffler M. Effect of high carbohydrate intake on hyperglycemia, islet function, and plasma lipoproteins in NIDDM. *Diabetes Care*. 1992;15:1572-1580.
48. Garg A, Bantle JP, Henry RR, et al. Effects of varying carbohydrate content of diet in patients with non-insulin-dependent diabetes mellitus. *JAMA*. 1994;271:1421-1428.
49. Tabatabai A, Li S. Dietary fiber and type 2 diabetes. *Clin Excell Nurse Pract*. 2000;4:272-276.
50. Jenkins DJ, Kendall CW, Axelsen M, et al. Viscous and nonviscous fibres, nonabsorbable and low glycaemic index carbohydrates, blood lipids and coronary heart disease. *Curr Opin Lipidol*. 2000;11:49-56.
51. Jenkins DJ, Axelsen M, Kendall CW, et al. Dietary fibre, lente carbohydrates and the insulin-resistant diseases. *Br J Nutr*. 2000;83(suppl 1):S159-S163.
52. Gutierrez M, Akhavan M, Jovanovic L, Peterson CM. Utility of a short-term 25% carbohydrate diet on improving glycemic control in type 2 diabetes mellitus. *J Am Coll Nutr*. 1998; 17:595-600.
53. Skov AR, Toubro S, Ronn B, et al. Randomized trial on protein vs carbohydrate in ad libitum fat reduced diet for the treatment of obesity. *Int J Obes Relat Metab Disord*. 1999;23:528-536.
54. Baba NH, Sawaya S, Torbay N, et al. High protein vs high carbohydrate hypoenergetic diet for the treatment of obese hyperinsulinemic subjects. *Int J Obes Relat Metab Disord*. 1999;23:1202-1206.
55. Parker B, Noakes M, Luscombe N, Clifton P. Effect of a high-protein, high-monounsaturated fat weight loss diet on glycemic control and lipid levels in type 2 diabetes. *Diabetes Care*. 2002;25:425-430.
56. Skov AR, Toubro S, Bulow J, et al. Changes in renal function during weight loss induced by high vs low-protein low-fat diets in overweight subjects. *Int J Obes Relat Metab Disord*. 1999; 23:1170-1177.
57. Kolasa KM. Dietary Approaches to Stop Hypertension (DASH) in clinical practice: a primary care experience. *Clin Cardiol*. 1999;22(suppl 7):16-22.
58. National Institutes of Health. *Facts About the DASH Diet*. Washington, DC: National Institutes of Health, National Heart, Lung, and Blood Institute; 1998. Publication 01-4082.
59. Karanja N, Obarzanek E, Lin PH, et al. Descriptive characteristics of the dietary patterns used in the Dietary Approaches to Stop Hypertension trial. DASH Collaborative Research Group. *J Am Diet Assoc*. 1999;99(suppl 8):S19-S27.
60. National Heart, Lung, and Blood Institute. Facts about the DASH diet. Available at: http://www.nhlbi.nih.gov/health/public/heart/hbp/dash/index.htm. Accessed October 8, 2002.
61. Williams RR, Hunt SC, Hasstedt SJ, et al. Genetics of hypertension: what we know and what we don't know. *Clin Exp Hypertens A*. 1990;12:865-876.
62. An P, Rice T, Gagnon J, et al. Familial aggregation of resting blood pressure and heart rate in a sedentary population: the HERITAGE Family Study. Health, Risk Factors, Exercise Training, and Genetics. *Am J Hypertens*. 1999;12:264-270.
63. Svetkey LP, McKeown SP, Wilson AF. Heritability of salt sensitivity in black Americans. *Hypertension*. 1996;28:854-858.
64. The fifth report of the Joint National Committee on detection, evaluation, and treatment of high blood pressure (JNC V). *Arch Intern Med*. 1993;153:154-183.
65. Kotchen TA, Kotchen JM, Grim CE, et al. Genetic determinants of hypertension: identification of candidate phenotypes. *Hypertension*. 2000;36:7-13.
66. Barak Y, Nelson MC, Ong ES, et al. PPAR gamma is required for placental, cardiac, and adipose tissue development. *Mol Cell*. 1999;4:585-595.
67. Barroso I, Gurnell M, Crowley VEF, et al. Dominant negative mutations in human PPARγ associated with severe insulin resistance, diabetes mellitus and hypertension. *Nature*. 1999;402:880-883.
68. Luan J, Browne PO, Harding A-H, et al. Evidence for gene-nutrient interaction at the PPARγ locus. *Diabetes*. 2001; 50:686-689.
69. Fasola AF, Martz BL, Helmer OM. Renin activity during supine exercise in normotensives and hypertensives. *J Appl Physiol*. 1966;21:1709-1712.
70. Walker WG, Whelton PK, Saito H, et al. Relationship between blood pressure and renin, renin substrate, angiotensin II, aldosterone and urinary sodium and potassium in 574 ambulatory subjects. *Hypertension*. 1979;1:287-291.
71. Svetkey LP, Moore TJ, Simons-Morton DG, et al. Angiotensinogen genotype and blood pressure response in the Dietary Approaches to Stop Hypertension (DASH) study. *J Hypertens*. 2001;19:1949-1956.
72. Cook NR, Cohen J, Hebert P, et al. Implications of small reductions in diastolic blood pressure for primary prevention. *Arch Intern Med*. 1995;155:701-709.
73. Conlin PR, Chow D, Miller ER 3rd, et al. The effect of dietary patterns on blood pressure control in hypertensive patients: results from the Dietary Approaches to Stop Hypertension (DASH) trial. *Am J Hypertens*. 2000;13:949-955.
74. Tuomilehto J, Lindstrom J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344:1343-1350.