A systematic review of nutrition-based practices in prevention of hypertension among healthy youth

Zeynep Begüm Kalyoncu[1], Hatice Pars[2], Nebahat Bora-Güneş[3], Erdem Karabulut[4], Dilek Aslan[5]

[1]Department of Nutrition and Dietetics, Hacettepe University Faculty of Health Sciences, Departments of Pediatric Nursing, [2] Hacettepe University Faculty of Nursing, Ankara, [3] Kırıkkale University Faculty of Health Sciences, Kırıkkale, and Departments of [4] Biostatistics and [5] Public Health, Hacettepe University Faculty of Medicine, Ankara, Turkey
E-mail: diaslan@hacettepe.edu.tr

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The aim of this systematic review was to analyze the results of observational and interventional research/studies on nutrition-based practices in the prevention of hypertension among healthy youth. The MEDLINE/PubMed database was searched using the key words, "hypertension," "nutrition/diet," "prevention" and "youth." Inclusion criteria were: 1) sample with a majority of adolescents, defined as 10-24 years of age, or findings for adolescents reported separately from other age groups; 2) primary research reports; 3) studies with normotensive participants; and 4) studies that focused on preventing hypertension/lowering blood pressure through at least one nutritional practice. Results of the analysis indicated that increased consumption of unsaturated fats, fruits, vegetables and low-fat dietary products, decreased consumption of dietary sodium and beverages containing caffeine, and breastfeeding were found to have preventive effects against high blood pressure in later years of life. The effects of training given during youth to encourage a healthy lifestyle and behavior changes based on diet and physical activity were also noted.

Key words: hypertension, nutrition, prevention, youth.

The World Health Organization defines the youth population as individuals from 10 to 24 years of age[1]. Since youth is a transitional period of physical, mental and social development, it is an important period for developing nutrition-related lifestyle habits, and active decision-making skills for personal choices[2]. Obesity, a sedentary lifestyle and a positive family history of hypertension may be predictive of the development of hypertension, especially in the period of adolescence (10 to 19 years of age).[3]

Despite its preventability, hypertension is a leading public health problem, affecting both the adult and youth populations in developing as well as developed countries. The prevalence of hypertension—a multifactor disease involving a combination of genetics, complex hemodynamic and metabolic mechanisms and environmental factors—among youth is increasing [3-5]. The long-term health risks of hypertension in youth are substantial. High blood pressure during childhood predisposes adults to hypertension, coronary heart disease and stroke[4,5]. Therefore, early modification of risk factors among youth through lifestyle changes may prevent or even reverse this progression. This makes youth an ideal target population for the primary prevention of cardiovascular diseases; yet this remains one of the major contemporary health challenges across the globe.

A number of research studies suggest a link between dietary factors and increased risk of developing hypertension. Among the current dietary recommendations for prevention of hypertension are: reducing intake of alcohol, sodium and caffeine; increasing potassium intake; adhering to a dietary pattern rich in fruits, vegetables and low-fat dairy products along with a reduction in total and saturated

fats[6-8]. Additionally, the Dietary Approaches to Stop Hypertension (DASH) dietary pattern, named after the Dietary Approaches to Stop Hypertension Trial, has proven to be effective reducing blood pressure (BP) levels in normotensive and hypertensive individuals[6,7]

Although the importance of nutrition-based practices in the prevention of hypertension among youth is very well known, there have been only a limited number of studies focusing on this specific topic. Recent published studies deal with the adult population in regard to hypertension treatment and prevention[9,10].

Moreover, the limited studies conducted among the youth population investigate topics such as treatment of hypertension in young people, prevention of hypertension among obese or overweight adolescents and general nutrition in youth; also found are cross-sectional studies that provide an estimate of the degree to which the prevalence of hypertension among youth is increasing[10-15]. Additionally, no systematic review to date has examined nutrition-based practices intended to prevent hypertension among youth.

Thus, the purpose of this systematic review is to document existing literature (up to June 2013) that discusses the prevention of hypertension through nutrition-based practices among healthy, normotensive youth.

Material and Methods

Literature Search

The search was conducted using the contents of the MEDLINE/Pubmed database from its inception up through June 25, 2013. For the literature search, we first employed the key words *hypertension*, *nutrition*, *prevention* and *youth*. We then performed three more literature searches, first replacing *hypertension* with *high blood pressure*, and second, replacing *nutrition* with *diet* in order to capture all relevant information. Therefore, we had in total four searches, with the following key words: 1) *hypertension*, *nutrition*, *prevention* and *youth*; 2) *high blood pressure*, *nutrition*, *prevention* and *youth*; 3) *hypertension, diet*, *prevention* and *youth*; and 4) *high blood pressure*, *diet*, *prevention* and *youth*.

The search strategy was developed in collaboration with an experienced statistician, who is one of the authors. Review of abstract titles and relevant full articles, as well as data abstraction, was performed in triplicate by two of the study authors; a third, independent author then evaluated the selected articles. Finally, disagreements regarding selection were resolved by consensus among all five of the study's investigators.

Study Selection

We selected quantitative studies in which observational and interventional methods were used to explore the role of nutrition-based practices in the prevention of hypertension among youth. Only studies reported in English were included. Other inclusion criteria were: 1) sample with a majority of adolescents, defined as 10-24 years of age, or findings for adolescents reported separately from other age groups; 2) primary research reports; 3) studies with normotensive participants; and 4) studies that were focused on preventing hypertension/ lowering blood pressure through at least one nutritional practice.

The exclusion criteria were: 1) research sample that is not in the predefined age range; 2) studies with participants who have chronic diseases such as obesity, diabetes, etc.; 3) studies that focused on hypertension prevention without any nutritional practices, i.e., through physical activity, parental support, etc.; and 4) reviews, meta-analyses and cross-sectional studies that provide information on the prevalence of hypertension among youth, as well as qualitative studies; and 5) studies that were focused on hypertension treatment, instead of prevention.

Data Synthesis

First, three authors independently selected the articles, and then two of them worked together to extract data; finally, the third author evaluated the selected articles independently to resolve any uncertainties. Three authors read all of the articles and finalized the manuscript according to the PRISMA 2009 checklist (16). PRISMA was used to assure the transparency and completeness of the systematic review owing to its comprehensive checklist.

Study Selection and Reporting

Of 410 citations identified, 356 studies were excluded on the basis of the abstracts, for reasons such as their being: studies published in a language other than English; reviews or meta-analyses; studies whose subjects were not

10-24 years of age; and studies unrelated to hypertension or nutrition. The 54 remaining studies were evaluated in detail, and 45 of these were excluded for comprising diabetic, non-normotensive, obese or overweight participants, or for focusing solely on physical activity. Overall, nine articles were included in the study (Fig. 1).

Results

Table I provides a summary of important points compiled during evaluation of the nine studies, which are listed in the table according to publication date (oldest first). All the studies were conducted after obtaining approval in regard to ethics. Among the 9 studies, 4 were randomized controlled trials (RCTs) comparing the effects of breast milk vs. baby formula, dietary counseling regarding a low-fat, low-cholesterol diet vs. a control diet, web-based family nutrition education vs. a control, and low-fat vs. high-fat dairy products on the prevention of hypertension among youth. Among these 4 RCTs, 3 of them reported the randomization procedure. Another 3 of the 9 studies were non-randomized interventional trials investigating the efficacy of a school-based health promotion study, the association between caffeine intake and ambulatory BP patterns, and the relation between dietary social support and compliance to a low sodium diet. Finally, there were 2 observational studies that were about assessing the effect of dietary patterns similar to DASH on blood pressure, and the association between lifelong fruit and vegetable consumption and pulse wave velocity.

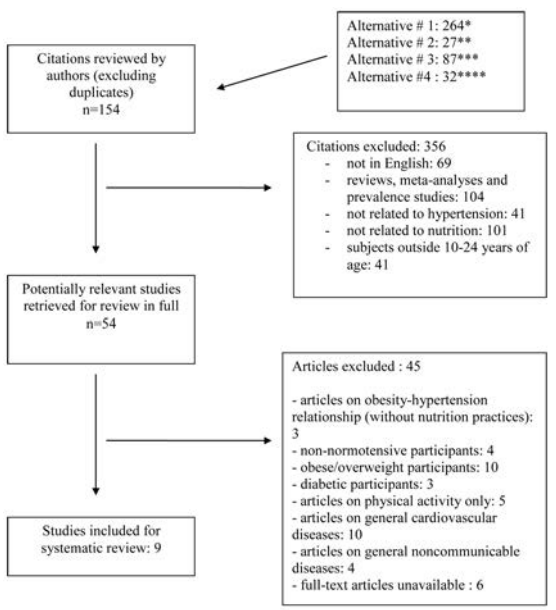

Fig. 1. Flow diagram of study selection
* Alternative # 1: 'hypertension', 'nutrition', 'prevention', and 'youth'
** Alternative # 2: 'high blood pressure', 'nutrition', 'prevention', and 'youth'
*** Alternative # 3: 'hypertension', 'diet', 'prevention', and 'youth',
****Alternative # 4: 'high blood pressure', 'diet', 'prevention', and 'youth'

All of the studies concerned the youth population, and all of them provided relevant background from the literature as well as a detailed description of the study sample. Although dosing and intervention strategies differed among the various studies, the outcome measures were similar: systolic and diastolic BP; and, in some studies, measures such as mean arterial BP, elevated BP risk, overnight rate of urinary sodium excretion and pulse-wave velocity.

We also documented the participant numbers of the studies in question. As shown in Figure 2, these numbers varied considerably.

We analyzed the included nine studies by classifying them into three subcategories: i) long-term studies dealing with nutritional practices that begin before youth, ii) studies dealing with direct nutritional practices on youth, and iii) studies dealing with nutrition and health promotion activities.

i) Long-Term Studies Dealing with Nutritional Practices That Begin Before Youth

Four articles concerned long-term studies dealing with nutritional practices that begin before youth and end either before 24 years of age or in adulthood[17,18,20,22]. All of these studies reported a significant effect as a result of the nutritional aspect being studied. In their RCT, Singhal et al.[17] examined the effects of early diet programs on BP in later life among preterm infants. A total of 926 preterm infants were randomly assigned in two parallel trials. In the first trial (n=502 infants), the effect of breast milk vs. preterm formula was investigated, with 253 infants assigned to breast milk and 249 to preterm formula. In the second trial (n=424 infants), the effect of term formula vs. preterm formula was investigated, with 211 infants assigned to term formula and 213 to preterm

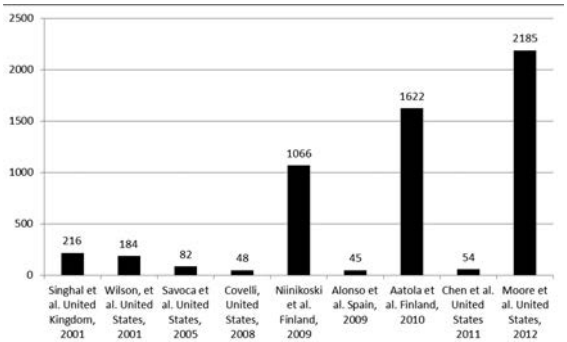

Fig. 2. Participant numbers of the studies included in the review

formula. After excluding those lost to follow-up, 216 children from the cohort of 926 newborns (23% of the original cohort) were measured for blood pressure at age 13–16 years. The breastfed preterm infants had significantly lower mean arterial pressure (p=0.001) and diastolic BP (p=0.016), but there was no significant difference for systolic BP. There was also no significant difference between term-formula-fed infants and preterm-formula-fed infants with respect to BP measurements.[17]

In the study done by Niinikoski et al.[18], the positive influence of a low-saturated-fat diet from infancy to 15 years of age was demonstrated. In this prospective RCT, the intervention group of healthy infants received individualized dietary and lifestyle counseling aiming at a fat intake of 30% to 35% of daily energy; a saturated to monounsaturated+polyunsaturated fatty acid ratio of 1:2; and a cholesterol intake of <200 mg/d (n=540). Later, when the children reached 8 years of age, guidance toward lower sodium intake was provided, although this was never the main subject of the intervention. Ample use of vegetables, fruits, berries, and whole grain products in the diet was also encouraged. The control group children received health education that required no modification in their diets (n=522). The BP of all the participants was measured every year from 7 months to 15 years of age. The results showed both systolic and diastolic blood pressures as being 1.0 mm Hg lower (95% CI for systolic: −1.7 to −0.2 mm Hg; 95% CI for diastolic: −1.5 to −0.4 mm Hg) in children receiving low-saturated-fat counseling throughout childhood than in the control children. Intakes of saturated fat were lower (p<0.001), those of polyunsaturated fat higher (p<0.001) and those of potassium slightly higher (p=0.002) in the intervention group, but sodium intakes were not influenced by the intervention (p=0.76).

In their observational cohort study, Aatola et al.[20] assessed the association between childhood and lifestyle risk factors using pulse wave velocity (PWV). The cohort study comprised 1622 subjects, aged 3 to 18 years, who were followed up for 27 years. As a significant result, vegetable consumption in childhood was inversely associated with adult PWV (β= -0.06, p=0.002). Secondly, high consumption of both fruits and vegetables from childhood to adulthood was associated with lower PWV than was persistently low consumption (p=0.03 for both).

Moore et al.[22] assessed the effects of an eating pattern similar to that of the Dietary Approaches to Stop Hypertension (DASH) study on adolescent BP. It was suggested that the DASH dietary pattern may have beneficial effects on changes in BP earlier in life. Data from 2185 girls followed up over 10 years (until the girls were 18–20 years of age) were used in this analysis. Diet was assessed during eight examination cycles using 3-day dietary records; girls were classified according to their consumption of foods associated with a DASH-style eating pattern. The dietary records were collected during study years 1–5, 7, 8 and 10. Blood pressure measurement criteria and additional information about the data collection tools were included. The results showed that participants who consumed 2 daily servings of dairy and 3 servings of fruits and vegetables had a 36% lower risk (95% CI=0·43, 0·97) of elevated BP in late adolescence. In longitudinal modeling, two dietary factors were associated with a lower systolic BP throughout adolescence: higher (2 daily servings) dairy intakes (p=0.0001) and a DASH-style pattern (p<0.001). Only the DASH-style pattern led to consistently lower diastolic BP levels (p=0.003).[22]

To sum up, these 4 studies highlighted the significant long-term BP-lowering effects of breast milk, a diet low in saturated fat beginning in infancy, and a diet rich in fruits and vegetables from infancy until adulthood.

ii) Studies Dealing with Direct Nutritional Practices on Youth

Two studies dealt with direct nutritional practices on youth, and one of them reported a significant effect as a result of the nutritional aspect studied[8,19]. In the study done by Savoca et al.[8], caffeine intake was shown to increase daytime systolic BP among adolescents. Data from 82 healthy, normotensive youths (15 to 19 years old)—a group comprising 41 African Americans (17 male and 24 female) and 41 non-Hispanic whites (29 male and 12 female)—were used in the analysis. All the subjects were provided with a sodium-controlled diet for 4 days (mean±SD sodium intake to 4000±200 mg/d). The leftovers were recorded, and the total amount of caffeine consumption was determined. In addition, all the participants performed an overnight urine collection, and ambulatory BP measurements were taken during both the day and the night. The result was that, regardless of ethnicity, a dose-response relationship was found: the higher the caffeine consumption, the higher the daytime systolic BP. There was no statistically significant difference in nighttime systolic BP across different amounts of caffeine consumption. African Americans had higher daytime diastolic BP than non-Hispanic whites. Finally, there was no statistically significant difference in overnight urinary sodium excretion across different amounts of caffeine consumption[8].

On the other hand, the study by Alonso et al.[19] failed to show a statistically significant difference in effect between low-fat and whole-fat dairy product intake on BP in young normotensive adults. In this crossover study, 45 normotensive volunteers (18–24 years old, 49% female) alternatively received 3.5 servings/day of whole-fat or low-fat dairy products (milk and yogurt) in addition to their usual diet for two 8-week periods, with a 4-week washout period between these interventions. The results showed that whole-fat dairy supplementation significantly increased systolic BP (2.1 mmHg, 95% CI = 0.1–4.0, P = 0.04) and weight (1.0 kg, 95% CI = 0.5–1.5, p = 0.0002), but not diastolic BP (p = 0.34). Weight and BP did not change significantly after the low-fat dairy intervention ($p>0.05$).

In short, according to these two studies, caffeine had the effect of increasing BP, while low-fat vs. whole-fat dairy products had no significantly different effect on BP.

iii) Studies Dealing with Nutrition and Health Promotion Activities

Three studies dealt with community-based nutrition and health promotion activities directed toward youth, and two of them reported a significant effect as a result of the approach studied[3,7,21]. In the RCT conducted by Chen et al[21]. fifty-four Chinese American adolescents aged 12-15 years and their families were provided with an online theory-driven, family-based program to promote a healthy weight and lifestyle. In the case of the families in the intervention group (n=27), adolescents received weekly session activities online for 8 weeks, and parents received three online sessions during the same 8 weeks. The intervention was designed to be individualized and was based on the Transtheoretical (Stages of Change) Model and social cognitive theory regarding the behavioral stage of the adolescent. The web-based program consisted of activities to enhance the self-efficacy of the adolescents in the intervention group and facilitate their understanding and use of problem-solving skills related to nutrition, physical activity and coping. The control group (n=27) received general health information that was neither individually tailored nor related to nutrition; instead, information on dental care, basic dermatology care, safety and risk-taking behaviors was provided. Anthropometric data, as well as data on BP, dietary intake, physical activity and knowledge and self-efficacy regarding physical activity and nutrition were collected at baseline and the second, sixth and eighth months. The results showed that in the intervention group, diastolic BP was significantly reduced from inception of the study to the second, sixth, and eighth months ($p<0.05$); no significant difference was found in systolic BP.

However, no significant difference overall was found in a similar study done by Covelli et al.[3] In order to determine the efficacy of a school-based health promotion intervention, a nine-week study was conducted on 48 participants (16 females, 32 males) who were 14-17 years of age. Participants were divided into an intervention and a control group. The nine-week intervention program consisted of two 90-minute classes per week and provided the cognitive behavioral components of health

knowledge, health promotion concepts, nutrition and exercise. The participants received in-depth lectures on healthy nutrition and did a minimum of 30 minutes of walking exercise once every week. They were encouraged to eat at least five to six servings of fruits and vegetables per day and to exercise for a minimum of 30 minutes each day. The participants in the control group were enrolled in another course called "Life Management," which did not deal with health knowledge. Although there was a significant difference between the two groups in the daily intake of fruits and vegetables and in the amount of exercise, after the nine weeks of the intervention period there was no significant difference in either mean BP or systolic BP.

In the final study, conducted by Wilson et al.[7], the relation between gender, dietary social support and compliance to a low-sodium diet was investigated. One hundred eighty-four healthy African American adolescents (101 females, 83 males) aged 13-16 years participated in an intensive 5-day low-sodium diet regimen (50 mEq/24 hr) as part of a hypertension prevention program. The role of family support in dietary compliance, and its relation to gender difference, was then measured. Compliance was defined as urinary sodium excretion ≤ 50 mEq/24 hr at post-sodium restriction. In the results of the study, systolic blood pressure showed a trend toward decreasing in compliant participants. Compliant girls reported higher levels of dietary support (19.2±7.8) from family members than did compliant boys (16.9±7.0). In contrast, compliant boys reported lower levels of dietary support than did noncompliant boys. Therefore, higher levels of emotional support from the family regarding diet were associated with better compliance to short-term sodium restriction for girls, whereas the association was the converse for boys.

Ultimately, health promotion activities that incorporated family members, such as the studies done by Chen et al.[21] and Wilson et al.[7], had a significantly higher BP-lowering effect. Among the three studies, the greatest effect was found in that by Chen et al.[21], which incorporated an individualized approach with a family-based program.

Discussion

Similarly to the review done by Spagnolo et al.[23], the results of this review showed that lifestyle and nutrition interventions, starting from childhood, were found to be key for the prevention of high blood pressure, because early life factors influence the development of hypertension in adulthood[24]. Among the articles included in this review, those studies that were based on long-term nutritional practices showed a more significant impact than did short-term studies. To begin with, the research by Singhal et al.[17] highlighted the importance of breastfeeding preterm infants as a measure for lowering blood pressure later in life. In the study, the effect of human milk was found to be independent of gestation time; therefore, the study has applicability to infants born at term as well. Since adult high blood pressure is partly rooted in early nutritional practices, breastfeeding could have a potential long-term protective effect. In a similar study, children who were breast fed for a minimum of three months had lower systolic and diastolic BP in adolescence compared to formula-fed children[24]. The study by Singhal et al.[17] found a 3 mmHg decrease in diastolic pressure among breast-fed infants. This result has remarkable implications for public health, since the analysis of the Framingham study states that a population-wide reduction of diastolic pressure by 2 mmHg would reduce the prevalence of hypertension by 17%[17]. The second study to support the claim that long-term nutritional practices have a beneficial role was Niinikoski's RCT[18] on 1066 children. In this study, participants who followed a low-saturated fat and -cholesterol diet from 7 months to 15 years of age were shown to have both systolic and diastolic pressures that were 1 mmHg lower that those of the control group. This finding is in line with the low cardiovascular mortality that is observed in communities that consume large quantities of fish and thereby omega-3 fatty acids, which are themselves polyunsaturated fatty acids[25].

According to the review done by Guardamagna et al.[26], the cardioprotective effects of breastfeeding were attributed to its influence on lipid metabolism, contributing to a lower level of total cholesterol. In another of the studies included in this review—Aatola's[20] observational cohort study of 27 years' duration—the more fruits and vegetables consumed by the participants, the lower the

blood pressure markers. These results are in parallel with current literature supporting the idea of hypertension prevention through the DASH diet, which recommends 8 to 9 servings of fruits and vegetables per day. This diet was shown to be effective in lowering BP and preventing hypertension, as well as contributing to reduction of the risk of hypertension-related complications. The benefits of the DASH diet in terms of hypertension prevention may also be attributable to its recommendations of 2-3 servings of low-fat dairy, a maximum of 2300 mg sodium, fat less than 27% of total calories, a minimum of 30 grams of fiber, 4700 mg of potassium and 500 mg of magnesium per day[10]. Therefore it is also not surprising to see the significant positive effects of a DASH-like eating pattern that were found in the study by Moore et al.[22]. These long-term nutritional studies that showed a significant impact on lowering blood pressure were also those that had higher numbers of participants, which increases the reliability of the results (Fig. 1). However, while recommending a decreased salt consumption as a requirement of the DASH diet, it is also important to note that certain polymorphisms, such as the CYP4A11 T8590C genotype in normotensive individuals, cause similar differences in BP during high and low salt intake. This genotype has no effect on the renal vasoconstrictor response to Angiotensin II during both high-salt and low-salt conditions[27]. Additionally, according to the Cochrane review published by Taylor et al.[28], despite the data from observational studies that indicate high salt intake to be an important cardiovascular risk factor, no significant association was found between salt intake and cardiovascular events along with total mortality[28]. Since statistical computation can differ from clinical reasoning and significance, it is important to note that the relationship between salt intake and cardiovascular risk remains controversial[29].

The two studies in the present review that dealt with direct nutritional practices on youth were conducted on a lower number of participants. While the BP-increasing effect of caffeine was shown to be significant in the study by Savoca et al.[8], Alonso et. al.[19] failed to demonstrate a significant difference in the effect of whole-fat vs. low-fat dairy products on BP markers. The BP-increasing effect of caffeine was also shown in another, similar study that measured the rise in blood pressure after caffeinated beverage consumption[8]. This is particularly important, because the consumption of caffeinated beverages, such as soft drinks, coffee, tea and hot chocolate, etc is quite prevalent among young people[30]. Furthermore, in a study done by Lane et al. [31], the average ambulatory BP of healthy participants was raised significantly, by 4/3 mm Hg, as a result of the effects of caffeine administration, which persisted for many hours during the activities of daily life.

In contrast, the study by Alonso et al.[19] failed to show a significant difference between whole-fat and low-fat dairy products in terms of lowering BP. This finding is surprising, because the intake of low-fat dairy products was associated with a lower BP in many studies[9,10,32]. In yet another study, the dairy consumption of 5880 normotensive university graduates in Spain, aged >20, was assessed, and low-fat dairy consumption, but not whole-fat dairy consumption, was associated with a lower risk of hypertension[33]. The mechanism behind the BP-lowering effect of dairy foods was explained by the presence of peptides that inhibit angiotensin-converting enzyme[34]. Actually this finding is, in a way, in line with the results of the study by Alonso et al.[19], in that since whole-fat and low-fat dairy products have the same protein components, and hence the same peptides, the BP-lowering effect of milk products could be attributed to their peptide content instead of their low fat content. As a matter of fact, Alonso et al. [19] found a significant increase in systolic BP following whole-fat dairy consumption, due to such products' saturated fat content. Although dairy products are to be recommended regardless of their fat content for their ability to lower BP, there is more evidence favoring low-fat dairy consumption in this respect.

According to the results of those studies examined in this systematic review that dealt with nutrition and health promotion activities, culture- and gender-specific, personalized studies that included a behavioral approach showed a significant BP-lowering effect. For example, in the study done by Chen et al.[21], an online family-based, behavior-change-theory-oriented program that lasted for eight months significantly reduced diastolic BP. In this study, the involvement of parents and a duration of

Table I. Summary of Articles Included in the Review

Author, Source (Country of origin, year that the study was published)	Objective	Sample Size*, Age Range	Duration and design of the study	Outcome measures related to blood pressure	Results	Recommendations
Singhal et al. United Kingdom, 2001[17]	To define the influence of early nutrition on BP	n=216, from birth till 13-16 years of age	13-16 years; two parallel RCTs. In the first RCT, one group received banked breast milk and the other, enriched preterm formula. In the second RCT, one group received term formula and the other, enriched preterm formula.	Systolic, diastolic, and mean arterial BP	Breast-fed preterm infants had significantly lower mean arterial pressure (p=0.001) and diastolic BP (p=0.016), but no significant difference for systolic blood pressure. There was no significant difference between term-formula-fed infants and preterm-formula-fed infants.	Breast-feeding is very important in early life nutrition of preterm infants for lowering blood pressure.
Wilson et al. United States, 2001[7]	To examine the relation between gender, dietary social support and compliance to a low sodium diet	n=184, 13-16 years of age	5 days; interventional trial. Participants were told to consume a low-sodium diet for 5 days after filling out the Social Support for Eating Scale. In the 5th day of the diet, urinary sodium, potassium excretion and creatinine were examined from 24-hour urine to determine compliance.	Systolic and diastolic BP; urinary sodium excretion	There was a significant decrease in SBP in sodium restriction diet- compliant participants.	Low-sodium diet for better blood pressure in healthy African American adolescent population.
Savoca et. al. United States, 2005[8]	To assess the association between caffeine intake and ambulatory BP patterns among adolescents	n=82, 15-19 years of age	4 days; pre-post interventional trial. Participants followed a 4-day sodium-controlled diet and in the 1st and 4th days of the diet period provided a 24-h ABP recording. Each day of the diet, the overnight urinary sodium excretion rate was determined.	Systolic and diastolic BP; overnight urinary sodium excretion rate	There was a significant difference in daytime SBP between the lowest and highest caffeine intakes. There was no significant difference in nighttime SBP and overnight urinary sodium excretion rate.	Caffeine consumption from beverages can contribute to elevated risk of hypertension. Therefore this issue should be investigated in youth at risk for hypertension.
Covelli United States, 2008[3]	To determine the efficacy of a school-based health promotion intervention	n=48, 14-17 years of age	9 weeks; interventional controlled trial. The intervention group participated in two 90-min classes per week on health knowledge, health promotion concepts, nutrition and exercise, and walked for a minimum of 30 minutes. They were encouraged to consume ≥5 servings of fruits and vegetables daily. The control group participated in a general Life Management course.	Systolic, diastolic and mean arterial BP	No significant difference in SBP, DBP or mean arterial BP between groups.	An intervention program that focuses on health promotion, knowledge and decision-making skills may be beneficial for adolescents at high risk for cardiovascular diseases.

Niinikoski et. al. Finland, 2009[18]	To define the influence of a low-saturated-fat diet from infancy to 15 years of age	n=1066, from first year till 15 years of age	15 years; RCT. The intervention group received individualized dietary and lifestyle counseling aiming at fat intake of 30 to 35% of daily energy; SAFA:MUFA+PUFA=1:2; cholesterol intake<200 mg/dL. The control group received only basic health education	Systolic and diastolic BP	Intervention group participants had both lower SBP (p=0.018) and DBP (p<0.001).	Individualized dietary counseling to limit SAFA intake, increase unsaturated fat, vegetable and fruit intake from infancy until 15 years of age to decrease both SBP and DBP.
Alonso et. al. Spain 2009[19]	To assess the effect of the intake of whole-fat vs. low-fat dairy products on BP	n=45, 18-24 years of age	20 weeks (2 8-week periods with a 4-week washout period in between); crossover RCT. Participants were randomly assigned to supplement their diets with whole-fat or low-fat dairy products for 8 weeks. After a washout period of 4 weeks (no dairy products were consumed), they received the alternative intervention for another 8 weeks.	Systolic and diastolic BP	Differences in changes in BP between the two interventions were not significant. After the whole-fat intervention, participants experienced a small but significant increase in SBP (p=0.04)	No benefit of low-fat dairy products compared with whole-fat dairy products in terms of BP. However, a possible undesirable effect of whole-fat dairy product intake in some individuals' SBP.
Aatola et al. Finland 2010[20]	To assess the association between childhood and adulthood lifestyle risk factors; measured in childhood and adulthood with pulse wave velocity in young adulthood	n=1622 from 3-18 years to 30-45 years	27 years; observational. Children and adolescents aged 3,6,9,12,15 and 18 were followed in 1983, 1986, 2001 and 2007, and risk variables were recorded.	Systolic BP, PWV	In adulthood, vegetable and fruit consumption was inversely and statistically significantly associated with lower PWV and cardiovascular risk factors (SBP). The association between SBP and PWV was statistically significant (p<0.0001).	Promoting good dietary habits in early childhood for the primary prevention of cardiovascular diseases.
Chen et. al. United States, 2011[21]	To examine the feasibility and efficacy of a theory-driven and family-based program delivered online to promote healthy lifestyles and weights in Chinese American adolescents	n=54, 12-15 years of age	8 months; RCT. The intervention group participated in a web-based program consisting of activities to enhance the self-efficacy of adolescents and facilitate their understanding and use of problem solving skills related to nutrition, physical activity and coping. The control group received only general health information.	Systolic and diastolic BP	In the intervention group, DBP was significantly reduced between inception of the study and the second, sixth, and eighth months (p<0.05). No significant difference in SBP.	A low-cost web-based behavioral program is effective in moving more families toward healthier lifestyles, positive behavior changes and better health outcomes.

Moore et. al. United States, 2012[22]	To assess the effects of a diet similar to DASH on adolescent BP	n=2185, from 9-10 years till 18-20 years of age	10 years; observational study. Diet was assessed using 3-day records during study years 1-5, 7, 8, 10. Blood pressure was measured annually	Systolic and diastolic BP, and elevated blood pressure (EBP) risk	Some aspects of the DASH diet, including higher intakes of nuts, seeds and legumes were associated with lower DBP ($p=0.003$); consuming ≥ 4 servings of fruits and vegetables, ≥2 servings of dairy products and ≥2 servings of low-fat dairy products led to reduction in EBP risk; higher intakes of dairy products alone and DASH pattern led to lower SBP ($p<0.0001$).	The DASH diet pattern may have beneficial effects on changes in BP early in life. Consumption of a diet rich in dairy products, fruits and vegetables during the early and mid-adolescent years is recommended.

longer than six months were cited as reasons for the program's effectiveness in terms of blood pressure management. In addition, the novel approach offered in the use of online tools for hypertension prevention was shown to be effective, similarly to what was shown in the study by Thompson et al.[35] In this study[36], an online obesity prevention program was helpful in promoting healthy diet and physical activity behaviors among 80 8-to-10-year-old African American girls at risk of obesity. Although the study by Chen et al.[21] reported no significant difference between genders in regard to the outcome measure, Wilson et al. found a difference between genders. In this study[7], they demonstrated that a higher level of emotional support concerning diet from the family members of females increased compliance, whereas an opposite effect was found for males. However, the duration of the study was only five days versus eight months for the study by Chen et al.[21] Therefore, the comparison lacks a standard duration of time. Moreover, there was a racial difference between the participants in the two studies: all participants in the study by Wilson et al.[7] were African Americans, while all those in the study by Chen et al.[21] were Chinese Americans. Therefore, the differing results can also be attributed to racial difference, even though Miles et al. found no evidence of racial invariance when they assessed familism and parental respect across race/ethnicity in adolescents[36].

We have some recommendations based on the results of our review. First, it must be noted that nutritional strategies for reducing hypertension risk factors in adolescents were investigated in a limited number of studies; therefore, more research is needed in this area. The studies we found to have the most significant results were the long-term, direct nutritional interventions that featured the DASH diet pattern or components thereof. Therefore, nutritional practices with a DASH-like pattern that start as early as possible should be recommended. Some aspects of the DASH diet, such as the effect of long-term fruit and vegetable consumption on blood pressure, were investigated in an observational manner. Thus, similar studies conducted in a RCT format could be useful to validate the findings. Lowering caffeine and encouraging breastfeeding are also highly important. Regarding health promotion activities, web-based programs that involve parents seem to be the most promising approach, especially if they are of long duration. Additional research on behavior programs is needed to more fully examine their effectiveness in promoting and maintaining changes in diet and physical activity levels. Also, the study of racial and gender differences with respect to the prevention of hypertension should be prioritized. Finally, we recommend more studies that incorporate a multidisciplinary approach through teamwork involving various professionals, such as dietitians, nurses, physicians, psychologists and educators.

In conclusion, rather than the consumption or avoidance of a single nutrient, nutritional practices with a DASH-like pattern that start as early as possible are recommended to prevent hypertension among adolescents. Lowering

caffeine and encouraging breastfeeding are also highly important. As for health promotion activities, individualized web-based, low-cost programs that involve parents seem to be the most promising approach, preferably with a duration long enough (at least 8 months) for habit formation.

Limitations of the study

Performing a meta-analysis would be the optimum way to analyze the data quantitatively; however, the data were quite heterogeneous. Plus, the number of studies that were deemed appropriate according to the inclusion criteria of the present review was only nine. Therefore, after consulting an expert statistician, it was decided that the best way to analyze the data was by performing a qualitative analysis. Secondly, we conducted our research using a single database (PubMed), which narrowed our research results. We attempted to compensate for that shortcoming by enlarging the literature search of the original topic with different variants of the initial keywords. We also scanned the database from the time of its inception rather than setting a specific date[19].

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