

A Systematic Review on the Relationship of Dietary Habits and Blood Pressure in the Pediatric Age Group

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Abstract

Background

Tracking of blood pressure from early life to adulthood and the increasing prevalence of elevated blood pressure in the pediatric age group are considered as important health issues. Rapid lifestyle change and dietary habits are considered as important determinants of this problem. This study aimed to systematically review the studies on the association of dietary habits and blood pressure in the pediatric age group.

Materials and Methods

The search was conducted from November 2015 to August 2016. Those papers were included that investigated the association of dietary habits on blood pressure in children and adolescents aged less than 18 years. The following medical subject headings and keywords were used to search all field (Diet OR nutrition OR nutrient OR food OR food habits OR food preferences) AND (Blood pressure OR hypertension OR high blood pressure OR systolic pressure OR diastolic pressure OR Systolic Blood Pressure [TIAB] OR Diastolic Blood Pressure [TIAB]) AND (child [Mesh] OR children [TIAB] OR adolescent [Mesh] [TIAB] OR pediatrics [Mesh] OR paediatric [TIAB])

Results

A total of 549 studies were initially identified in the databases. After excluding duplicate studies, 270 articles were retrieved and we reviewed them based on their titles and abstracts; then 161 articles were selected for more detail review. Findings of multiple studies showed the beneficial effect of fruits, vegetables and dairy products on blood pressure in children.

Conclusion

Increasing evidences indicate that dietary habits, notably daily salt intake of children is directly related to their blood pressure level. Our findings serve as confirmatory evidence on the necessity of paying more attention to primordial and primary prevention of hypertension.

Key Words: Adolescent, Blood Pressure, Child, Diet.

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1- INTRODUCTION

At the present time hypertension is one of the most important health problems of societies. Approximately 7.6 million of early death happens due to hypertension and also the reason of about 54% of strokes and 47% of Ischemic heart disease is related to hypertension (1, 2). Systematic analysis of different societies' health statistics shows that elevated blood pressure is the most important reason of death in the world and the second prevalent reason of death in children after underweight (3). According to studies of World Health Organization (WHO), none communicable diseases are often preventable. However, 40% of deaths in developing countries and 75% in developed countries are due to the mentioned diseases (4).

Changing epidemiological pattern of diseases in developed and developing countries and life expectancy increase, escalation of stress resulting from urbanism, indolence, change of dietary habits and hypertension are the most important risk factors leading to serious cardiovascular diseases (5). The most significant adjustable factors affecting blood pressure are as following: elevated blood sugar, obesity, elevated blood cholesterol, indolence, alcohol intake, tobacco smoking, stress and long-term use of oral contraceptives. Non-adjustable factors are as following: age increase, gender, race and genetic factors (6). There are a lot of evidences in various studies showing that high salt intake (sodium chloride) is an important factor that increases blood pressure in adults (7-9).

Proper planning to regularly control blood pressure, dietary habits control through reducing salt intake, calorie restriction to prevent obesity, cholesterol and saturated fat intake reduction, eliminating environmental and mental stresses, doing sports regularly and controlling blood

pressure medications can significantly prevent getting blood pressure and its effects. (6). At the present time hypertension control at industrial countries radically decreased number of deaths due to cardiovascular diseases, strokes and kidney damages.

Increasing evidences show that elevated blood pressure in childhood is a predictor of getting hypertension in coming stages of life. Studies indicate that elevated blood pressure in childhood is a risk factor of getting atherosclerosis disease in the future (10). Although blood pressure in infants is mostly of secondary type and happens due to an underlying disease which is usually intense, but can be treated if diagnosed, however nowadays essential elevated blood pressure happens in young children which is usually slight and symptomless, but in long period leads to cardiovascular and kidney damages. Many factors such as genetic, dietary habits, stress and obesity are effective in essential hypertension (11). American Academy of Pediatrics recommends blood pressure measurement of all over 3-year-old children in child care businesses (12, 13). In various age studies prevalence of elevated blood pressure in children is reported to be 5.4 to 9.4% (14). Dietary habits are considered of important determinants of elevated blood pressure in adults, limited experience exist in the pediatric age group. As hypertension origins in early life, special attention has been drawn to the association of dietary factors with blood pressure in children and adolescents, and even from fetal period. Various dietary habits are considered as risk factor or protective factor for the mean and elevated blood pressure of children and adolescents. Salt intake is considered as an important risk factor, whereas consumption of some healthy foods including fruits, vegetables, and dairy products might have protective effects. Findings of clinical, epidemiological, and experimental studies show that salt can

have a role in regulating blood pressure in children and adolescents; moreover, it is shown that reducing salt intake might be beneficial for blood pressure in children (17-19). However, controversies exist in different studies. This study aimed to systematically review the studies that have assessed the relationship of dietary habits with blood pressure in pediatric age group.

2- MATERIALS AND METHODS

2-1. Literature Search Strategy

In the present study, we searched the following databases: Medline, ISI web of Science, Scopus, Embase and Google Scholar. The search was conducted from November 2015 to August 2016, and papers published until November 2015 were included. Those papers were included that investigated the association of dietary habits on blood pressure in children and adolescents aged less than 18 years. The

following medical subject headings and keywords was used to search all field in the above databases: (Diet [Mesh], dietary [TIAB] OR nutrition [TIAB] OR nutrient [TIAB] OR food [Mesh] OR food habits [Mesh] OR food preferences [Mesh]) AND (blood pressure [Mesh] OR hypertension [Mesh] OR high blood pressure [TIAB] OR systolic pressure [TIAB] OR diastolic pressure [TIAB] OR systolic [TIAB] OR diastolic [TIAB] OR Systolic Blood Pressure [TIAB] OR Diastolic Blood Pressure [TIAB]) AND (child [Mesh] OR children [TIAB] OR adolescent [Mesh] [TIAB] OR pediatrics [Mesh] OR paediatric [TIAB]). An additional manual search was performed using reference lists from the research studies and review articles to identify other eligible studies. The flow chart of study selection process is presented in **Figure.1**.

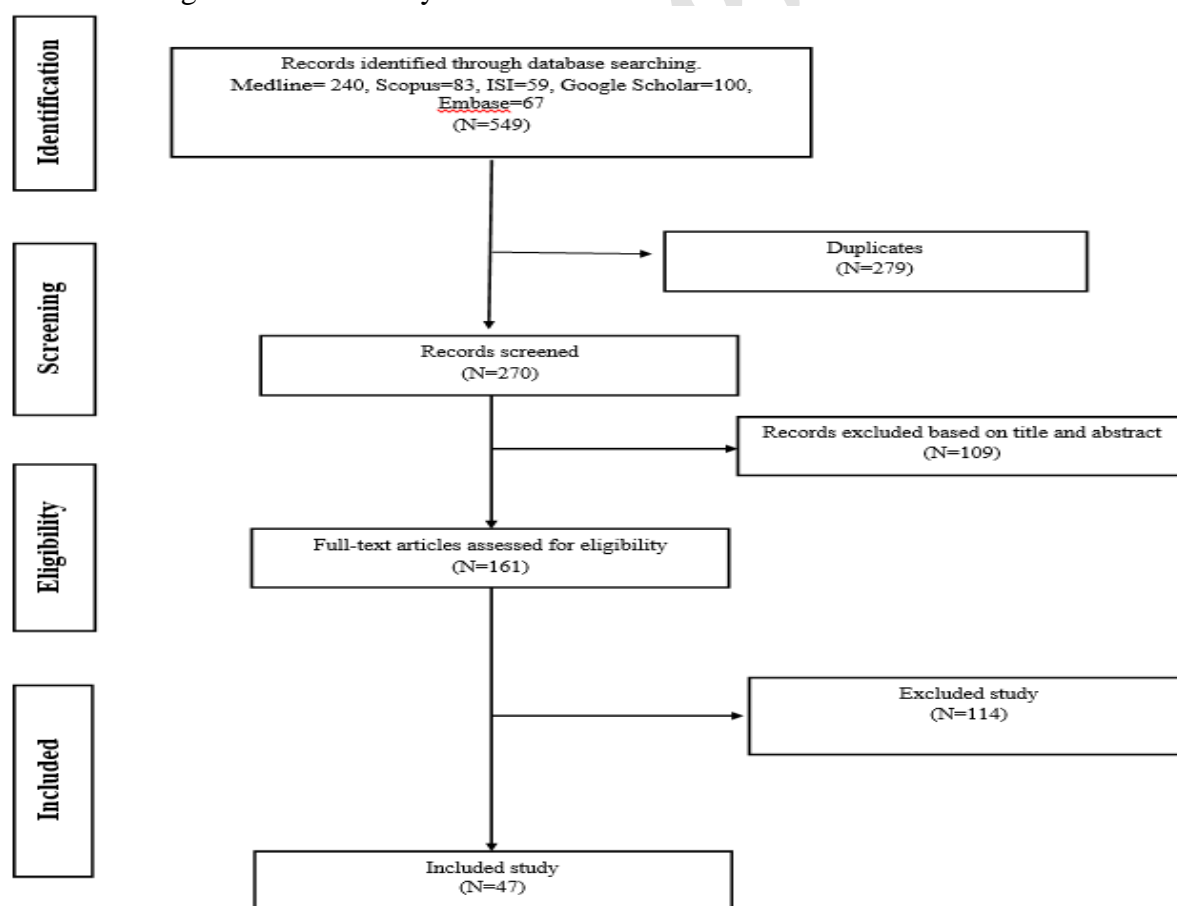


Fig.1: The strategy of selection process

2-2. Data Selection

There was no time limitation for choosing the articles and all papers published until August 2016 were included in the first step. Relevant English language articles were identified by searching databases without any restriction by study design. All published papers on the relationship of dietary habits and blood pressure in children and adolescents aged less than 18 years were included. Additional published reports were obtained by cross-matching references of selected articles that fulfilled our eligibility criteria. Our review was restricted to human subjects. Using the saved searches and auto alerts automated facilities incorporated within the MEDLINE database.

Duplicated, irrelevant and non-human subjects studies were excluded. Researchers retrieved full-text of the remaining studies for further examination. Studies were excluded that considered the relation of blood pressure in patients or adult. In addition, studies that assessed diet with weight loss intervention or hypocaloric diet intervention that lead to weight loss were excluded. Only studies that investigated diet and food intake through Food Frequency Questionnaire (FFQ) questionnaires, 24-hour recall or food record were included and others that assessed food intake through parameters in blood or urine were excluded. Some studies assessed the relationship between metabolic syndrome or cardiovascular disease risk factors and diet that blood pressure did not assess separately. Thus these studies were excluded.

2-3. Quality Assessment

For quality assessment, we considered our study eligibility criteria, study design, sample size, sampling method, and measurement tools. The Newcastle-Ottawa Scale (NOS) for cohort studies, the adapted NOS for cross-sectional study and the Jadad quality assessment score for

randomized clinical trial were used to assess the methodological quality of the included studies. The NOS, 'a star system' is based on three board perspectives: the selection of the study groups; the comparability of the groups; and the ascertainment of either the exposure or outcome; the Jadad is based on three aspects: randomization, blinding and withdrawals. Three researchers retrieved full-text of the included studies for further examination. Also, any disagreements and discrepancy on study selection were resolved by the first investigator (Roya Kelishadi).

2-4. Data Extraction

Data were obtained based on the first author name, country name, study type and findings. They are presented according to the relevance between blood pressure and dietary habits.

3- RESULTS

A total of 549 studies were initially identified in the databases. After excluding duplicate studies, 270 articles were retrieved and we reviewed them based on their titles and abstracts, 161 articles were selected for more detail review. According to findings, it seems that children who consumed 4 or more servings of fruits and vegetables per day or 2 or more servings of dairy products per day during the preschool years had smaller yearly gains in systolic blood pressure throughout childhood (20). There is inverse associations between systolic blood pressure and calcium, magnesium, potassium, protein and fiber and direct associations between systolic blood pressure and total fat and monounsaturated fat. In addition, there is inverse associations between diastolic blood pressure and calcium, magnesium, potassium, protein, carbohydrates and fiber and direct associations between diastolic blood pressure and polyunsaturated fat and monounsaturated fat (21).

It is well documented that any action reducing daily salt intake from people and specially children's diet can significantly reduce its negative effects in coming years of life (22). According to conducted studies, amount of sodium intake in diet has a direct relation with blood pressure. On the other hand, elevated blood pressure is one of the most important causes of cardiovascular disease (including stroke, heart attacks, ventricular hypertrophy, and heart infarction). Hypertension has become a major health problem in recent years specifically in developed and industrial societies. Nutritional transition, rapid changes in dietary habits, and tendency to use industrial processed foods, as well as sedentary lifestyle are the main determinants of elevated blood pressure both in children and adults (23).

Children follow their parents in consuming processed foods and therefore, if salt used in processed foods is reduced the salt intake of children reduces as well. A meta-analysis study taken from 10 controlled trial studies in this field shows that 42% reduction of salt intake results in a fall in blood pressure of 1.17 to 1.29 mmHg (24). Moreover, a recent study indicated a similar result that blood pressure falls as salt intake reduces. Although, the mentioned rate is a slight reduction, but this slight amount in childhood blood pressure can lead to positive health and hygiene effects in individuals (25). Salt intake reduction in children accompanied with reduction of drinking sweet drinks can have a significant role in preventing childhood obesity (25, 26). The characteristics of the included studies are summarized in (Table.1) (please, see the end of paper). The findings of this systematic review focused on dietary habit for example salt consumption, fruit and vegetable intake on blood pressure in the pediatric age group.

4- DISCUSSION

4-1. Salt Intake and its Relation with Blood Pressure

There are many studies showing firmly that amount of salt intake is one of the major factors of hypertension in societies. The variety and clarity of evidences existing in this field is much more than other life style factors such as overweight, low intake of fruits, vegetables and physical inactivity.

4-2. Genetic Studies on Human

In terms of human physiology there are, also many causes of this disease. Findings of studies show that kidneys function to desalinate blood decreases and therefore blood pressure increases. The opposite of this statement is also, correct if kidneys are unable to balance the salt of blood and ward off much salt, the blood pressure decreases which can be balanced by increasing amount of salt intake. These studies clearly show the importance of salt intake in blood pressure regulation (28, 29).

4-3. Epidemiological Studies

Epidemiological studies are conducted on the basis of comparing societies with low blood pressure and societies in which blood pressure of people doesn't change much as they get older. Although, other factor may be involved in it, but generally results of various studies confirm the role of salt intake in blood pressure regulation. For example, an epidemiological study conducted on residents of Pacific Ocean, showed that blood pressure of native people using sea water (saltwater) in their diet is higher than those who use freshwater (30). A seven-year follow up study was conducted by Geleijnse et al. on the effect of salt intake through dietary habits and amount of sodium and potassium intake and its effect on blood pressure among 233 children aged from 5 to 17 years old in Germany. Findings of the study showed that elevated blood

pressure in children has a significant relation with amount of sodium/potassium of urine (31). Generally taking into account the existing evidences and data collected from diverse human societies of the world, it seems that in order to confront hypertension (due to sodium intake) in adults, the maximum daily sodium intake of each person must be less than 2.3 grams per day. When sodium exceeds this amount, it causes hypertension with a direct linear ratio and therefore affects body organs. In children because of lower Body mass index (BMI), even small amount of blood sodium can be effective in blood pressure increase (32).

4-4. Salt in Children

4-4-1. Infants

A double-blind control case study on 500 infants shows that by reducing 30% of salt intake (which can be measured from urine sodium concentration), progressive changes of infants' systolic blood pressure decreased in comparison with control group infants taking normal amount of salt (33). When 6 months of the study ended, it became clear that systolic blood pressure of infants taking fewer amount of salt in their food was 2.1 mmHg lesser ($P < 0.01$). The study was stopped after 6 months and 15 years later 35% of the participant children were followed up. In this group after confounding factors were balanced, a significant difference was observed between the two groups and it was revealed that individuals whose salt consumption was less in their first 6 months of life have lower blood pressure in comparison with other individuals (18).

4-4-2. Children and Adolescents

Various epidemiological studies conducted until now on salt intake and blood pressure of children and adolescents reveal different results and they generally don't show a strong relationship in this field. Lack of this relationship can be due to daily

changes of salt intake in individuals. Moreover many of these studies are problematic in regard of research methodology; for example the methods used to estimate amount of salt intake are not very reliable. Clinical studies with a more reliable research methods (for example measuring amount of salt intake and sodium existing in urine and controlling confounding factors of experiment), mostly show a positive significant relation between salt intake and amount of blood pressure increase in children and adolescents (34, 35).

For instance a controlled study with high precision was conducted by Cooper et al., in which 7 times of urine during 24 hours were collected from 73 children aged from 11 to 14. The findings showed that there is a linear significant relation between urine sodium and systolic blood pressure of the children in a way that high salt intake caused elevated blood pressure (17). In the study all confounding factors such as age, gender, race, heartbeat, height and weight were under control. A meta-analysis study conducted on 10 clinical trial studies, with population of 996 individuals, showed that reducing the average daily salt intake significantly affects blood pressure of children and adolescents. By 42% reduction of salt intake for an average period of 4 weeks, the systolic blood pressure decreased 1.2 mmHg ($P < 0.001$) and diastolic blood pressure decreased 1.3 mmHg ($P < 0.001$). These findings are of prime importance to evaluate blood pressure in children whose childhood elevated blood pressure can cause adulthood hypertension in them (36). A low salt diet, if continued, can be effective in preventing hypertension as the age gets older.

4-5. Amount of Edible Salt Intake

Amount of salt intake has increased in children, because of eating too much of processed and ready-made foods. In 1984

a study was carried out in England in which sodium of two 24-hour consecutive urine, in preschoolers aged between 4 and 5 years old was investigated. The findings showed that the amount of sodium expelled daily was about 4 grams in average (37); and if it is equalized on the basis of adults' weight, this value will be about 15-20 grams a day which is a high number for children. Besides this, the study was carried out at a time when processed-food intake was low in children, but at the present time salt intake in children of developing countries has increased due to eating processed and ready-made foods (38). Eating snacks, fast-foods and restaurant foods which are usually highly salted, has increased drastically and made the salt intake of children aged over 3 or 4 years at the same range of adults' salt intake.

In the beginning lower levels of salt intake was recommended for children, but after a number of consultations and due to some general reasons this level was increased. For instance, Scientific Advisory Committee on Nutrition (SACN) recommended 5 g/d of salt for 7-year-old children (39) which was very high, because WHO's recommended salt intake for adults was less than 5 g/d (40). It is crystal clear that salt intake in children is much more than recommended amounts. It should also, be mentioned that this suggested dosage of salt intake is not the optimal amount for good health, however, this amount is available. Physiological need of human is very lower than recommended dosages [for example Yamomamo Indian natives use less than 0.5 g/d of salt in their diets (41)].

Findings of a number of studies show that salt intake is high in almost all age groups of children. For example the amount of sodium expelled through urine is 4.1 g/d in 6-year-old Finnish children (42). This amount was 7.8 g/d in 10-12 years Portuguese children (43). A similar study

carried out in Australia on primary school children aged between 5 and 13, shows the amount of expelled sodium in 24-hour equal to 6 g/d (44). A review study conducted by Brown et al. investigated 41 reports from 20 countries in regard of amount of salt intake in all age groups and in both genders from different countries. In their study the salt intake of adults in the U.S.A, Japan and Australia was reported to be more than 12 g/d; but the study was not mainly involved with urine sodium (45).

A sectional study was done in the England on three age groups of 5-6 years old, 8-9 years old and 13-17 years old children. The purpose of the study was investigating amount of salt intake. Findings showed that salt intake of 5-6 age group was 3.75 g/d. This amount increased to 7.55 g/d in 13-17 age groups. This increase of salt intake was significant in both girls and boys ($P < 0.001$). Moreover, in the same age groups salt intake concentration was considerably high in boys than girls ($P < 0.001$). Researchers of the study justified their findings by stating that older children as compared to younger children and also, boys as compared to girls are more active and need higher levels of energy and therefore consume more food and accordingly their sodium intake is also higher (39). Considering this, it seems that increase in salt intake and following that the high blood pressure is unavoidable as we age. On the other hand, studies carried out on native Indians of Yanomamo and other isolated tribes don't show such a pattern of aging in high blood pressure. These groups of isolated tribes, because of their special food culture, use a small amount of salt and this small amount doesn't lead to hypertension with aging (41).

4-6. Diet Based on Fruits, Vegetables and Dairy

One of the most common ways to treat and prevent obesity in children is trying to

limit consumption of fatty foods and low energy dense foods. On the other hand, restricting consumption of low energy dense foods may cause irreversible reduction of child's appetite and as a result reduction of micronutrients required for child's growth. One of the alternative methods in this field which can be trained to parents and children is eating healthy foods such as fruits and vegetables rich in nutrients. This is among the important purposes of public health interventions (46). In the dietary guidelines for Americans (2005) the amount of nutrient and energy contributions from each food group are calculated according to the nutrient-dense forms of food in each food group (47).

Although researchers are aware of the important role of diet in blood pressure and obesity of children, but due to the complexity of these studies and existence of many confounders, few epidemiological studies are carried out in this field until now. Generally, it is observed that people following vegetarian diet, known as Mediterranean diet, have lower blood pressure compared with Eastern diet (48, 49). Besides this clinical trial studies show that eating fruits, vegetables and low-fat dairy foods lead to lower blood pressure in individuals suffering from hypertension (50). In studies related to hypertension, sodium is given a lot of attention. A meta-analysis study conducted on 56 studies related to this field, indicate that reducing sodium intake among individuals having hypertension can effectively reduce high blood pressure in adults; however this effect was paler in healthy people (51).

Studies show that a diet rich in fruits, vegetables and low-fat dairy can be effective in blood pressure regulation. Moreover comparative studies carried out on the effect of macronutrients and micronutrients on children's blood pressure show that on the whole high sodium intake is in relation with increase

of blood pressure in childhood. There are a few number of uncertain studies conducted about the effect of potassium, calcium and magnesium on childhood blood pressure. An interventional study on 8-11 year-old children having a Low Density Lipoprotein (LDL) diet, show that calcium, magnesium and potassium have a reverse role on blood pressure (52). Although a diet rich in milk and its products is full of calcium, magnesium and potassium and also a diet with a lot of fruits and vegetables is full of potassium and magnesium, but it isn't obviously clear yet to what extent the beneficial effect of dairy, fruits and vegetables is related to the mentioned 4 nutrients.

A case-control study was carried out on children to find an answer for this question. In the study 95 children aged between 3 and 9 were studied for 8 years. Research findings showed that systolic blood pressure of children eating large amounts of fruits and vegetables (4-time or more per day) or dairy products (2- time or more per day) in pre-school ages increase less in childhood and by aging. Findings also, showed that blood pressure range of children consuming large amounts of fruits and vegetables or only dairy products was between blood pressure of control group children (not receiving large amounts of both dairy products and fruits and vegetables) and children receiving large amounts of both dairy products and fruits and vegetables. The results of the study showed that both fruits and vegetables diet and low-fat dairy diet can be effective in blood pressure regulation in childhood (53).

4-7. Diet in Fetal Period and Infancy

At the present time a special attention is given to the role of intrauterine environment and infant's nourishment in future cardiovascular risks (54). It is supposed that cardiovascular condition of every person is dependent on his/her

intrauterine condition and nutrition in early life. Experiments done on animals confirm this statement, but in regard of human being there isn't enough evidence yet (55).

Researchers assume that babies born with low weight, due to intrauterine malnutrition and its relation with postnatal weight gain are disposed to abdominal obesity, metabolic syndrome, diabetes, Cardiovascular disease and adulthood diseases. On the other hand, overdue babies through consequences of maternal insulin resistance and glucose intolerance may be disposed to higher levels of obesity risk in the future (56). Moreover, studies carried out on nutrition of expectant mothers (for instance evaluation of protein and calcium) show that diet of pregnant mothers may also, affect baby's blood pressure (57, 58). However there isn't enough evidence to confirm this.

Breast milk is the best exclusive food for infant's feeding and is a source that must be measured in comparison with other strategies of infant feeding (59). Breast milk is full of saturated fat and cholesterol, but with low sodium. Many studies are done investigating the relationship between breastfeeding and risk factors due to cardiovascular diseases. Although making combinational estimations of these studies is difficult, because of differences in exposure and evaluation of findings, but the recent meta-analysis studies don't provide a significant effect of breastfeeding and the following effect on mortality due to cardiovascular disease (60). On the contrary systematic review studies confirm the positive effect of breastfeeding in prevention of future hypertension and obesity (61, 62). Results of other clinical trial studies and case-control studies, also show that breastfeeding in infancy leads to lower blood pressure in childhood (63, 64). Besides this, although breastfeeding may increase cholesterol level of infant's blood in the first year of life, but this may have a

role in lowering blood cholesterol level in adulthood (65).

Data in some ways confirm the strict relationship between food habits, hypertension and lifestyle. Results indicated that higher sugar-sweetened beverage (66), sweets (67), fructose (68) and added sugars (69) consumption is associated with higher serum uric acid levels and systolic blood pressure. In addition, studies suggested that a dietary rich in fruit, salad, cereals, fish (70, 71), low-fat dairy products (71-74) and vegetable protein (75) could contribute to primary prevention of hypertension when instituted at an early age. An excess use of salt (76, 77), cheese and red processed meat (78), western dietary pattern (79) could explain the greater rate of hypertension found among children and adolescents (76).

However, some findings showed no detectable relationships between blood pressure and calorie-adjusted intakes of fats, carbohydrates, sodium, potassium, calcium, or magnesium (80, 74), fast food or breakfast (81, 82) and dietary fiber (83).

4-1. Limitation of study

The major limitation of the present review is the scarcity of eligible studies and substantial variability between them. However, other limitations include bias and residual confounding for dietary assessment, different methods of dietary assessment.

5- CONCLUSIONS

At the present time the importance of nutritional and scientific studies to improve cardiovascular health of children has become more evident than before. Diverse investigations from around the worlds show that elevated blood pressure in children especially in school-going ages is more prevalent than before. Disregarding the level of blood pressure increase, it should be taken into account

that individuals suffering from elevated blood pressure or even pre-hypertension in childhood will most probably get cardiovascular disease and its negative effects in adulthood. On the other hand, it should be considered that in comparison with adults the maximum dosage of sodium intake in children is less due to their low Body mass index (BMI) and therefore in their diet low-sodium foods must be used. Moreover, various studies indicate the role of other micronutrients existing in children's diet in regulating their blood pressure. Inclusion of dairy products as well as fruits and vegetables in children's diet has positive outcomes on systolic their blood pressure balance. When both of these food groups are included in daily diet the outcome is more desirable. Although, a lot of studies carried out in this field have similar findings, but the need to conduct stronger clinical trial studies and designs are steel felt in order to obtain more definite results.

According to studies, one of the other factors effective on blood pressure in infancy and childhood is infant's diet specifically in the first year of life. As research findings show, breastfeeding has a reverse effect on blood pressure rate. Although the rate of this effect is slight, but this slight amount in terms of public health and in comparison with bottle feeding, has significant role in preventing hypertension as adults. Controlling BMI through increasing physical activity and reducing saturated acids intake and cholesterol intake, can also affect hypertension prevention especially in adolescence. Generally, it can be said that if before adolescence hypertension prevalence is dealt with suitably through diet control, the negative health effects of it, is prevented in adulthood and life expectancy in increased in people and also, treatment costs of countries' health and treatment systems especially in the field of non-communicable diseases, might be

reduced. Our findings serve as confirmatory evidence on the necessity of paying more attention to primordial and primary prevention of hypertension from early life.

6- CONFLICT OF INTEREST: None.

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Table-1: Characteristics of studies included in the review

Reference	Population size	Age	Study design	Dietary assesment	Food item	Results	Quality
Moore Lynn et al. (20)	95	3-6 year	Cohort (8 years of follow-up)	3-day food diaries during each year	Intakes of fruits and vegetables and low-fat dairy products (the DASH diet)	Results suggest that a diet rich in fruits, vegetables, and dairy products may have beneficial effects on blood pressure during childhood.	8 stars
Simons-Morton et al. (21)	662	8-11 years	Cross-sectional	Three 24-hour dietary recalls	Micronutrients such as calcium, magnesium, and potassium; the macronutrients such as protein, carbohydrates, total fat, saturated fat, polyunsaturated fat, and monounsaturated fat; dietary cholesterol; and total dietary fiber	Results from this sample of children with elevated low-density lipoprotein cholesterol indicate that dietary calcium, fiber, and fat may be important determinants of blood pressure level in children.	9 stars
He et al. (35)	1658	4-18 years	Cross-sectional	7-day dietary record	Salt intake	There was a significant association of salt intake with systolic blood pressure as well as with pulse pressure after adjusting for age, sex, body mass index and dietary potassium intake.	10 stars
Ribeiro et al. (65)	39	8-12 years	Clinical trial 2 groups: hypocaloric diet plus exercise training and hypocaloric diet	During 16 weeks, energy intake was 1400 kcal/d	Hypocaloric diet consisted of 50% to 70% carbohydrates, 10% to 15% protein, and 15% to 30% fat	Diet plus exercise training, in contrast to diet alone, significantly increased forearm vascular conductance responses during exercise.	3 scores
Nguyen et al. (66)	4876	12-18 years	Cross-sectional	24-hour dietary recall	Sugar-sweetened beverages included fruit drinks, sports drinks, soda, and sweetened coffee or tea	Results indicate that higher sugar-sweetened beverage consumption is associated with higher serum uric acid levels and systolic blood pressure, which may lead to downstream adverse health outcomes.	10 stars

Payab et al. (67)	14880	6-18	Cross-sectional	Subjects reported how many times they had consumed each Junk food items (daily, weekly, and seldom).	Junk food was divided into four categories, including salty snacks, sweets, sweetened beverages, and fast food.	The intake of sweets was significantly associated with BP levels.	10 stars
Bobridge et al. (68)	814	13-15	Cross-sectional	3-day food records	Fructose intake	In multivariate linear regression models, we did not see a significant association between fructose and blood pressure in boys or girls.	9 stars
Kell et al. (69)	320	7-12	Cross-sectional	Two 24-h dietary recalls	Added sugar (sugars not naturally occurring in foods)	Added sugars were positively associated with diastolic blood pressure.	8 stars
McNaughton et al. (70)	1086	12-18	Cross-sectional	108-item food frequency questionnaire	3 dietary patterns including fruit, salad, cereals, and fish pattern; high fat and sugar pattern; and vegetables pattern	The fruit, salad, cereals, and fish pattern was inversely associated with diastolic blood pressure after adjustment for age, gender, and physical activity. This study suggests that a dietary pattern rich in fruit, salad, cereals, and fish pattern may be associated with diastolic blood pressure in adolescents.	10 stars
Julian-Almarcegui et al. (71)	2283	12.5-17.5	Cross-sectional	24-hour dietary recall	Dairy products included milk, yoghurt, cottage cheese and milk and yoghurt beverages. High-sugar foods included sugar, honey, jam, cakes, pies, biscuits, confectionery and carbonated drinks. Savoury snacks included chips, salty biscuits, crackers and pop corns.	Significant but small inverse associations between fish and dairy products consumption with blood pressure have been found in European adolescents. Dietary intervention studies are needed to explore these associations in the context of the modification of several risk factors for the prevention of cardiovascular diseases.	10 stars

Falkner et al. (72)	180	14-16	Cross-sectional	24-hour intake recall	Dietary micronutrients	Among adolescents at risk for hypertension, BP was lower in those with higher intakes of a combination of nutrients, including potassium, calcium, magnesium, and vitamins. Dietary benefits on blood pressure observed on diets rich in a combination of nutrients derived from fruits, vegetables, and low-fat dairy products could contribute to primary prevention of hypertension when instituted at an early age.	8 stars
Gopinath et al. (73)	4720	12-17	Cross-sectional	Semi-quantitative food frequency questionnaires	Dairy food consumption (milk, cheese, yoghurt) and dietary calcium intake	In girls, after multivariable adjustment each serve/day increase in total dairy intake was concurrently associated with decreases in mean diastolic and arterial blood pressure. Also in girls, each serve/day increase in cheese intake was concurrently related to decrease in mean systolic, diastolic and arterial blood pressure. Among girls increase in dietary calcium intake was associated with a concurrent decrease in mean systolic and arterial blood pressure. Consumption of dairy products, particularly cheese, could have a beneficial effect on blood pressure particularly among girl.	10 stars

Yuan et al.(74)	610	8-10	Cross-sectional	Three nonconsecutive 24-hour dietary recalls	Dairy product consumption	High dairy intake (≥ 2 servings of dairy per day) was associated with 1.74 mm Hg lower systolic blood pressure ($P < 0.05$) and with 0.87 mm Hg lower diastolic blood pressure ($P = 0.10$) compared with low intake. We found no significant association of calcium, magnesium, or potassium intake on children's blood pressure, suggesting the role of other antihypertensive components in dairy products. Our results indicate that high intake of dairy (≥ 2 servings per day) has antihypertensive effects on blood pressure among youth.	9 stars
Gopinath et al. (75)	699	12 and 17	Prospective	Self-reported and based on a single question	Frequent takeaway food consumption	Frequent takeaway food consumption at the age of 12 years was not associated with anthropometric indices and blood pressure at the age of 17 years. Consumption of takeaway foods became more frequent during adolescence, particularly among boys, and it was associated with reduced intake of fruits and vegetables.	10 stars
Menghetti et al. (76)	2007	6-17	Cross-sectional	Food frequency questionnaire	Breakfast consumption and the intake of the following food: fruit, cooked and fresh vegetables, bread and pasta, meat, fish, milk, cold cuts, potatoes, cheese, eggs, salty and sweet snacks.	An excess use of salt could explain the greater rate of hypertension found among children/adolescents living in the north Italy.	10 stars

Shi et al. (77)	435	4-18	Cross-sectional	3 days weighed dietary records	Salt, fruit and vegetable consumption	1 g/d increase in salt intake was associated with a 0.2 mmHg increase in systolic blood pressure. A 100 g/d lower fruit and vegetable intake was related to a 0.4 mmHg higher blood pressure value. In healthy children and adolescents with blood pressure in the low-normal range, both salt intake and fruit and vegetable intake may already start to influence blood pressure, although at a small magnitude.	9 stars
Farajian et al. (78)	2024	10-12	Cross-sectional	Semi-quantitative food frequency questionnaire	Seven dietary components (patterns) were extracted.	A dietary pattern that is characterized by high cheese and red processed meat consumption increases the likelihood of having high BP in children, probably through increasing dietary sodium intake. These findings could guide future interventions or public health initiatives to prevent the increasing rates of childhood elevated BP levels.	10 stars
Hojhabrimanesh et al. (79)	557	12-19	Cross-sectional	168-item semi-quantitative food frequency questionnaire	Three major dietary patterns were identified	Western dietary Pattern (abundant in soft drinks, sweets and desserts, salt, mayonnaise, tea and coffee, salty snacks, high-fat dairy products, French fries, and red or processed meats) is associated with higher blood pressure in Iranian adolescents.	8 stars

Jenner et al. (80)	884	9 years	Cross-sectional	Food frequency questionnaire (completed by parents)	Daily energy intake and intakes of 14 nutrients	Diastolic pressure in boys was negatively related to energy intake and to calorie-adjusted fiber intake. Mean adjusted diastolic pressure in boys in the top fiber-intake quartile was 2.5 mm Hg lower than that in the bottom fiber-intake quartile. Systolic pressure in girls was negatively related to calorie-adjusted intakes of protein and cholesterol. There were no detectable relationships between blood pressure and calorie-adjusted intakes of fats, carbohydrates, sodium, potassium, calcium, or magnesium.	10 stars
Marlatt et al. (81)	368	11-18	Cross-sectional	Breakfast and fast food consumption were assessed using a self-report survey using validated questions	Breakfast and fast food consumption	Blood pressure was not associated with either fast food or breakfast	8 stars
Ahadi et al. (82)	13486	6-18	Cross-sectional	Self-reported questionnaire	Food habits	Blood pressure was categorized into three groups (normal, prehypertension, and hypertension), which they did not differ significantly between non-skipping (eating breakfast 5-7 days/week) students and breakfast skippers (eating breakfast 0-2 days/week)	10 stars
van Gijssel et al. (83)	2032	12 months- 6 years	Population-based prospective cohort study	211-item semiquantitative food-frequency questionnaire	Dietary fiber	There was no significant association between dietary fiber intake and blood pressure.	10 stars

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Gilardini et al. (84)	448	6-18	Cross-sectional	7-day diet history method	Food preparation and portion size at home; food intake and portion size at school, frequency and portion sizes of snacks consumed were assessed.	After adjustment with confounders blood pressure was negatively related to vegetable protein	9 stars
Gopinath et al. (85)	858	Mean age of 12.7 years	Cohort	120-items semiquantitative food frequency questionnaires	High Glycemic Index and Glycemic Load Diets	Excessive dietary intake of carbohydrates, specifically from high glycemic index/glycemic load foods, could adversely influence blood pressure, particularly in girls, whereas fiber-rich diets may be protective against elevated blood pressure during adolescence.	10 stars
Rangan et al. (86)	335	18 months- 8 years	Birth cohort	Food records	Dairy consumption	Children in the highest quintile of dairy consumption at 18 months had lower systolic blood pressure (SBP) and diastolic blood pressure (DBP) at 8 years. SBP was lowest among children in the highest quintiles of calcium, magnesium and potassium intakes. Significant negative linear trends were observed between SBP and intakes of dairy serves, calcium, magnesium and potassium. These results are consistent with a protective effect of dairy consumption in childhood on blood pressure at age 8 years.	10 stars
Agarwal et al. (87)	5099	2-18	Cross-sectional	24-h recall dietary interviews	Lunch meat intake	Lunch meat intake was not associated with any physiological measurements including blood pressure in children age 2-18 years.	9 stars

Brazionis et al. (88)	1229	6 month-7 years	Birth cohort study	Carer-completed questionnaires	Transition diets (spanning the 18-mo period from 6 to 24 month of age)	The less-healthy diet was associated with an increase in systolic blood pressure and diastolic blood pressure. A less-healthy transition diet by age 2 y was associated with higher blood pressure at 7.5 y. The BMI-related reduction in effect size reinforces the importance of BMI on the diet-BP relation.	10 stars
Chellappah et al. (89)	271	8-16	Randomized controlled trial (8 weeks)	50-item questionnaire	Impact of a school based intervention of providing fruit daily in the classroom	The change in systolic and diastolic blood pressure, heart rate, and 12-minute run distance covered, in intervention and control groups were significantly different between baseline values.	3 scores
Crispim et al. (90)	276	2-5	Cross-sectional	A questionnaire about dietary ingestion, validated for children aged from two to five years	Healthy diet (vegetables, fruits, milk and derivatives) and markers of an unhealthy diet (charcuterie, cookies, sodas and candies).	Regular intake of milk and derivatives showed an inverse association with high BP. However, regular intake of vegetables, fruits, sodas, candies and charcuterie was not associated with BP elevation.	8 stars
Mager et al. (91)	26	7-18	Randomized controlled trial (6 month)	3-day prospective food records (2 weekdays and 1 weekend day)	Diets high in added fructose (high fructose corn syrup; HFCS) and glycemic index (GI)/glycemic load (GL)	Dietary reductions in total/free fructose/HFCS and glycemic load were related to reductions in SBP. No changes in DBP were observed in either group over 6 months.	3 scores
Liao et al. (92)	615	9.6 ± 0.6 years	Cross-sectional	Semi-quantitative food frequency questionnaire (FFQ)	Healthy dietary habits	Healthy dietary habits and high fitness levels is synergistically associated with a remarkably lower prevalence of metabolic syndrome among Chinese children. However, systolic blood pressure did not associated with healthy diet separately.	8 stars

Rinaldiet al. (93)	147	6-10	Cross-sectional	Three 24-h dietary recalls	Basic food groups: cereals, legumes, vegetables, fruits, meats and egg (red meat, chicken, fish, and egg), and dairy food (milk, yogurt and cheese), oil and fat group and sugar group.	There was not any significant association between food groups and blood pressure as one of the component of metabolic syndrome.	7 stars
Novotny et al. (94)	85	5-8	Two-arm, randomized, controlled trial (9-month)	2-day food records	Pacific Kids DASH for Health (PacDASH)	Fruit and vegetable intake decreased less in the treatment than control group. Diastolic blood pressure was 12 percentile units lower in the treatment than control group after 9 months of intervention. There were no group differences in systolic blood pressure or body size/composition.	4 scores
Eloranta et al. (95)	402	6-8	Cross-sectional	4-day food records	Dietary quality indices: Dietary Approaches to Stop Hypertension (DASH) Score, Baltic Sea Diet Score (BSDS), Mediterranean Diet Score (MDS), and Finnish Children Healthy Eating Index (FCHEI).	There was not any association between each dietary quality indices and blood pressure.	8 stars

Eloranta et al.(96)	512	6-8	Cross-sectional	Food records of four consecutive days	Daily number of main meals and snacks and food consumption	Higher consumptions of non-root vegetables and red meat were associated with higher levels of systolic blood pressure. A higher consumption of red meat and a lower consumption of vegetable oils were independently associated with higher levels of diastolic blood pressure. After further adjustment the consumption of red meat was no longer associated with the levels of systolic and diastolic blood pressure and the consumption of vegetable oils was no longer associated with the levels of diastolic blood pressure.	8 stars
Damsgaard et al. (97)	523	8-11	Cross-sectional	7-day dietary records	Dietary components in the schools meals (school meals based on the New Nordic Diet (NND) increased the intake of fish, vegetables, and potatoes, thereby increasing the intake of dietary fiber and protein and reducing the intake of fat).	The New Nordic Diet did not any significant effect on blood pressure.	8 stars
Asghari et al. (98)	425	6-18	Prospective follow-up surveys.	168-item food frequency questionnaire	Dietary Approaches to Stop Hypertension (DASH)-style diet.	A significant association between higher adherence to the DASH-style diet and a 70% decreased risk of developing elevated blood pressure after 3.6 years of follow-up was observed.	9 stars

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Saneei et al. (99)	60	11-18	Cross-over randomised clinical trial	3 day dietary record (two week days and one weekend day)	Dietary Approaches to Stop Hypertension (DASH diet versus usual dietary advice (UDA)	Although changes in systolic blood pressure were not statistically significant between the two groups recommendations to follow the DASH diet prevented the increase in diastolic blood pressure compared with UDA.	10 stars
Kelishadi et al. (100)	35	12-18	Randomized clinical trial	Diet, containing 30% energy derived from fat, 15% from protein, and 55% from carbohydrate, with energy content based on the calorie requirement for height	Optimized mixed diet	No significant changes were observed in participant heart rate and systolic blood pressure and diastolic blood pressure.	10 stars
Niirikoski et al. (101)	1062	7 months- 15 years of age	Prospective randomized Special Turku Coronary Risk Factor Intervention Project Study	4-day food records	Low-saturated fat low-cholesterol diet	Systolic and diastolic blood pressures were 1.0 mm Hg lower in children receiving low-saturated-fat counseling through childhood than in control children. Restriction of saturated fat from infancy until 15 years of age decreases childhood and adolescent blood pressure with a meaningful population-attributable amount. The importance of childhood lifestyle counseling and primary prevention of hypertension should be emphasized, especially in those children with a family history of hypertension or atherosclerotic vascular disease.	10 stars

Skilton et al. (102)	3457	8-15 years	National Health and Nutrition Examination Survey	Two 24-hour dietary recalls	Long-chain ω -3 fatty acids eicosapentaenoic acid and docosahexaenoic acid	High-dietary intakes of eicosapentaenoic acid and docosahexaenoic acid are associated with lower systolic blood pressure and pulse pressure in children born with reduced birth weight. These data are consistent with the hypothesis that long-chain ω -3 fatty acids reduce blood pressure in those with impaired fetal growth.	10 stars
Sinaiko et al. (103)	210	10-14	Randomized clinical trial	Food records	3-year sodium reduction or potassium supplementation	These results showed that dietary sodium and potassium changes within the first two decades of life can reduce blood pressure in girls. Differences in blood pressure response between boys and girls suggest different sensitivities to supplemental potassium or dietary sodium change.	10 stars
Ayer et al. (104)	616	8 years	Randomized controlled trial	Food records	Dietary supplementation with n-3 and n-6 polyunsaturated fatty acids	There was no significant vascular benefits of a dietary supplement intervention of n-3 and n-6 on BP and comprehensive measures of arterial structure and function at age 8 years old.	10 stars

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Woodruff et al. (105)	1068	10-14	Cross-sectional	24 h diet recall	Salt consumption	Na intake was not associated with either SBP or DBP.	9 stars
Gómez-Marín et al. (106)	643	5-8	Randomized controlled trial	Food records	Reduction in dietary sodium and/or an increase in potassium intake	Results from this study will provide information about the feasibility and effect of dietary intervention during childhood and adolescence on the prevention of essential hypertension.	10 stars
Howe et al. (107)	100	11-14	Cross-over randomized clinical trial	Food records	Sodium intake	Dietary sodium restriction alone has little potential for lowering blood pressure at an early age, even in children with higher than average blood pressure.	10 stars
Couch et al. (108)	57	11-17	Randomized clinical trial	3-day diet recall	Diet high in fruits, vegetables, and low fat dairy	Diet intervention decrease significantly SBP z scores from baseline.	10 stars

Stars: Quality assessment according to the Newcastle-Ottawa Scale (NOS) for cohort studies. Quality assessment according to the adapted NOS for cross-sectional study;
 Scores: Quality assessment according to the Jadad quality assessment score for clinical trial studies.