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EFFECT OF VARIOUS DIETARY PATTERN ON BLOOD PRESSURE MANAGEMENT: A REVIEW

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ABSTRACT

Hypertension is a major contributor to the burden of cardiovascular morbidity and mortality worldwide as 25% of the world's adult population suffers from hypertension. For people with cardiovascular disease, adherence to a healthy diet has benefits additive to drug therapy and associated with reduction in mortality of between 8 and 45%. This review focuses the effect of various dietary patterns on blood pressure management. General search of academic journals (English) on diet, dietary pattern, blood pressure, hypertension and risk published from 2010 to 2019 was conducted. A total of 20 studies were selected from two electronic databases (PubMed, Science Direct). Eleven of the studies were from United States, one from Canada, China, Italy, Australia, Denmark, Spain, Germany, Brazil and Netherland. Twenty studies showed reduction in Systolic Blood Pressure (SBP) which range from 0.60 mmHg to 20.79 mm Hg and the highest reduction in SBP was from combination of Dietary Approach to Stop Hypertension (DASH) diet with low sodium intake. Diastolic Blood Pressure (DBP) nitrate-rich vegetable diet indicated highest reduction where it ranges from 0.60 mm Hg to 9.00 mm Hg. Fruits and vegetables intake should be practice to prevent the burden of non-communicable disease. This is great importance to public health and to reduce medical costs.

Key words: Blood pressure, diet, dietary pattern, hypertension, risk

INTRODUCTION

The American Heart Association (AHA) have defines stage one hypertension as those present with systolic blood pressure more than 130 mmHg and diastolic blood pressure more than 90 mmHg (AHA, 2013). Hypertension is one of main factors that contribute to heart failure, stroke and chronic kidney disease. Since hypertension is asymptomatic, most of the hypertensive patients did not realize that they have high blood pressure.

Worldwide, cardiovascular disease (CVD) risk has been increasing concomitant with the increase of blood pressure among the population. Almost 1.39 billion adults aged more than 20 years old have hypertension (Mills *et al*., 2016). This caused a global burden to the world because it also increased the mortality, morbidity, and the financial cost of the country. Still, the awareness of hypertension was low in developing countries compared to developed countries (Mills *et al*., 2016). Hypertension is known as the most leading causes for cardiovascular disease and had been estimated to cause more than 13% of deaths annually. At least 78 million American adults age 20 years old and above have hypertension or at least are taking anti-hypertensive medication (AHA, 2013). As the hypertension increasing with age, for elderly that age more than 60 years old the prevalence was 63.1% in the United States which shows more than half of the elderly population in US have hypertension and only 49.4% have controlled hypertension (Fryar *et al*., 2017). According to Sowers *et al*. (2001) almost 75% of cardiovascular diseases (CVD) in diabetes patients were caused by hypertension (Sowers *et al*., 2001). Therefore, current urge to reduce the prevalence of hypertension in the world to save the cost burden in treating CVD by modifiable risk factor of hypertension which are dietary intake.

Numerous factors have been identified as major risk factors for hypertension, such as dietary factors,

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physical inactivity, smoking and stress. Of these, one of the important modifiable risk factors in incidence of hypertension was dietary factors. As the food industry in our century had grown rapidly, consumer tends to choose the cheapest, easiest and fastest way to consume food without considering the nutritional value. Thus, throughout these several years many researches has been done to identify the dietary pattern that help to reduce blood pressure in population. Therefore, this review will focus on the effect of dietary patterns that reduce the systolic and diastolic blood pressure.

RESULTS

A total of 20 articles were selected and included in this review based on the inclusion criteria. Nine types of diet had been identified in this review. There are Mediterranean diet, Dietary Approach to Stop Hypertension (DASH) diet, dietary portfolio, low-fat diet, whole grains diet, Nordic diet, consumption of nuts, consumption of nitrate-rich vegetables and dietary supplements. This article summarises the effect of the diet to the SBP and DBP.

Mediterranean diet

Mediterranean diet (Med diet) was first introduced in Greece and Italy in 1960 where it generally emphasized to take food low in saturated fat and high in vegetable oils. The guidelines include to take high amount extra virgin olive oil, vegetables, fruits, cereals, nuts, and legumes while having moderate intake of fish, poultry, meat, dairy products and red wine and a small amount of eggs and sweets (Davis *et al*., 2015). In addition, the red meat and the processed meat are also limited in this diet (Pergola *et al*., 2018). Per day, people are encouraged to take one tablespoon of extra virgin oil (14.8 ml), consume 5 to 6 servings of vegetables, $\geq$ 2 serving fresh fruits, and 4 to 6 servings of wholegrain cereals. Meanwhile, having three serving of legumes, three serving of fish and < 1 serving of red meat per week is allowed. Discretionary food such as confectionery, chocolate, crisps, pastries, cakes, pies and other bakery products, biscuits, deep-fried foods, non-red wine alcoholic beverages, and oils and fats other than olive oil is limit to $\leq$ 3 times per week (Davis *et al*., 2017). According to three articles that we found, the results indicated a significant reduction in systolic and diastolic blood pressure where it ranges from 2.0 mmHg to 6.2 mmHg and 0.6 mmHg to 2.1 mmHg respectively (Davis *et al*., 2017; Storniolo *et al*., 2017; Vitale *et al*., 2018). The Med diet intervention period was given up to one-year intervention.

DASH diet

DASH diet have been introduced by emphasized the hypertensive patients to take food high in fruits, vegetables, nuts and low dairy products. The diet also suggest to consume chicken and fish rather than the red meat and food that low in saturated fat, cholesterol, sugar and refined carbohydrates. The first trial of DASH was in 1999 with participants that have untreated SBP and DBP in the United States (Sacks *et al*., 1999). In this review, we found that DASH diet intervention to the pre or stage 1 hypertension DASH diet with low sodium levels where it only allowed 1150 mg of sodium showed the highest amount of reduction in SBP where it reduced 20.79 mmHg (Juraschek *et al*., 2018).

Meanwhile, the high-fat DASH diet when given to the healthy participants shows reduction about 3.8 mmHg in the SBP. The high-fat DASH diet means they replace the non-fat and low-fat dairy product to full fat dairy products. For 2100 kcal of energy, this diet will provide 43% of carbohydrate, 18% of protein and 40% of fat. Then, for the fat 14% of it must come from Saturated Fatty Acids (SFA), 18% from Monounsaturated Fatty Acids (MUFA) and 8% from Polyunsaturated Fatty Acids (PUFA) (Chiu *et al*., 2016). In addition, DASH diet that used either lean pork, chicken and fish as source of protein also give the same result in reducing blood pressure since there was no significant difference between them (Sayer *et al*., 2015). In DASH diet with lifestyle modification, where the participant need to follow DASH diet with physical activity for one week have shown a significant reduction in both SBP and DBP. The physical activity was to walk for 15 to 20 min/day, 5 times/week with 25 to 30 calories provided per body weight. The macronutrients are same as other DASH diet which contains 55% of carbohydrate, 18% of protein and 27% of fat (Paula *et al*., 2015). The full details of the result are shown in Table 1.

Dietary portfolio

Dietary portfolio was the diet that included soy protein, viscous fiber and nuts in the diet. Specifically, in dietary portfolio for every 1000 calories diet, they target 9.8 g of viscous fiber, 22.5 g of soy protein, 22.5 g of nuts and 0.94 of plant sterols which usually comes from food that have been enriched with plant sterol esters. In one of the study, dietary portfolio significantly reduced the SBP and DBP by 2.1 mmHg and 1.8 mmHg, respectively. However, the significant reduction can only be seen at 24 weeks of the intervention (Jenkins *et al.,* 2015).

Low-fat diet

Low-fat diet can reduce the weight (Hu *et al*., 2012). However, in one of the study, they found that low-fat diet able to reduce the SBP and DBP in postmenopausal women. In that study, they only allow the participants to take total fat for 20% from the total calorie intake per day. In addition, the vegetables and fruits intake were increased to at least five servings per day while the grain was increased to six times per day in that study (Allison *et al*., 2016). The full results as shown in Table 1.

Whole-grains diet

Whole grain diet was known as one of the diet that helps to reduce weight. However in one of the study, it showed that whole grain diet had significant reduction in DBP for obese or overweight people by taking 50 g of whole grains per 1000 kcal per day. For the SBP reduction, whole grains diet reduce the SBP, but the reduction was not differ than the refined grains diet. In that study, the intake of whole-grain diet was based on the main cereals which were wheat, rice and oats (Kirwan *et al*., 2016).

Nordic diet

Nordic diet was developed in Nordic region where the diet was actually based on the Nordic food such as rapeseed oil, wholegrain cereals from rye and oats, berries such as blackcurrant and bilberry, fish such as salmon and cod, vegetables such as cabbage and root vegetables, fruits such as pear and apple and low fat dairy products such as skimmed milk (Brader *et al*., 2013). This diet provides 45 to 52% of carbohydrate, 18 to 20% of protein and 30 to 35% fat per day from total energy intake. For the total fat, 15% of the fat should be MUFA and 5% from it should be PUFA. In addition, 15 to 20 g of fiber per day also had been encouraged in this diet. Nordic diet was introduced for the Nordic country since the Med diet was not suitable for the Nordic region. Med diet was not suitable for Nordic region because of the differences in the local taste and culture. Nordic diet had shown significant reduction in both SBP and DBP in overweight to obese participants. Further detail on the reduction was shown on Table 1.

Consumption of nuts

In this review, we found that consumption of almond and walnut significantly reduced the SBP and DBP (Dhillon *et al*., 2016; Rock *et al.,* 2017). In a study that consumed walnuts, the reduction for SBP and DBP were 6 mmHg and 5 mmHg, respectively. The intake of walnuts were 42 g for ≥1500 kcal/day and 28 g for <1500 kcal/day. Meanwhile, for almond, the reduction was 3.11 mmHg in SBP and 1.07 mmHg in DBP with consumption of almonds about 15% from total energy intake per day.

Consumption of nitrate-rich vegetables

There was one study that shows by consume 800 mg nitrate-rich vegetables such as beetroot, salad and spinach reduce the SBP in a range from 5 to 7 mmHg while the DBP in a range 4 to 8 mmHg (Jonvik *et al*., 2016). The further result was as shown in Table 1.

Dietary supplementation

Recently numerous supplements have been introduced as one of alternative in reducing blood pressure such as quercetin from onion skin extract powder, cholecalciferol, nitrate supplementation, Grape Seed Extract (GSE), freeze-dried blueberry and whole foxtail millet diet (Berry *et al*., 2016; Bressendorff *et al*., 2016; Brüll *et al*., 2015; Hou *et al.,* 2018; Johnson *et al*., 2015; Park *et al*., 2016). 170 mg of quercetin per day reduced SBP and DBP by 3.60 and 2.10 respectively (Brüll *et al*., 2015). Meanwhile, 3000 IU cholecalciferol (Bressendorff *et al*., 2016) 140 ml of beetroot juice, 22 g of freeze-dried blueberry powder, 50 g of pure foxtail millet and 150 mg of GSE per day have significant reduction on SBP and DBP (Berry *et al*., 2016; Hou *et al*., 2018; Johnson *et al*., 2015; Park *et al*., 2016). Supplement was easy to consume by the consumer since the consumer did not have to modify their whole diet.

DISCUSSION

In this review, dietary intake that increase fruits and vegetables intake along with sodium reduction showed the greatest reduction of blood pressure. Increase intake of fruits and vegetables can reduce the blood pressure through it various nutrients and phytochemicals content, including fiber, potassium and folic acid. Since fruits and vegetables contain high in potassium, increasing potassium intake actually can lower the blood pressure through it vasodilatory effect and can reduce the resistance to blood flow in the vessels which results in reducing the blood pressure (Adrogué & Madias, 2007). Even though the actual mechanism of how fruits and vegetables can reduce the blood pressure remain unclear since it most likely to have many factors, it is still important to include fruits and vegetables in daily intake to reduce the blood pressure (Bazzano & Serdula, 2003). As studied by Ndanuko *et al*. (2016) they found that DASH diet, Nordic diet and Mediterranean diet were the most effective diet to reduce blood pressure.

Table 1. Type of intervention and reduction range of SBP and DBP

Country	Study	Purpose of the Study	Participants characteristics	Type of Intervention	Period of Intervention	Reduction of SBP (mmHg)	Reduction of DBP (mmHg)
Italy	(Vitale *et al.,* 2018)	To evaluate the relation of a Mediterranean diet pattern and its individual components with the cardiovascular risk factors profile, plasma glucose and body mass index in people with type 2 diabetes.	Diabetic patient; allowed anti-hypertensive drugs; n=2568; age 50-75 years old; male: 1534; female: 1034.	Mediterranean diet based on 9 key food groups: fruits, vegetables, legumes, cereals, fish, olive oil, meat and meat products, dairy products, and alcohol.	6 months	2.00	2.10
Spain	(Storniolo *et al.,* 2017)	To analyze whether Traditional Mediterranean Diet induced changes on endothelial physiology elements that involved in blood pressure control.	Non-smoker women, type 2 diabetes patients; on anti-hypertensive drugs; n=90; age 60 to 80 years old.	Traditional Mediterranean Diet with 52g extra virgin olive oil.	12 months	5.60	0.60
Australia	(Davis *et al.,* 2017)	To determine the effects of adhering to the consumption of a Mediterranean diet for 6 months on blood pressure and endothelial function in elderly.	Healthy participants; no medication stated; n=149; age 64 years older; male: 65; female: 84.	Consume Mediterranean Diet which is based on plant foods, extra virgin olive oil and reduced intake of red meat and processed food.	6 months	6.20	1.80
United States	(Juraschek *et al.,* 2017)	To compare the effects of low versus high sodium, DASH versus control and both by baseline blood pressure.	Pre or stage 1 hypertension patient; not on anti-hypertensive drugs; n=412; mean age: 48 years old; male: 177; female: 235.	DASH diet with low sodium levels at 1150 mg of sodium.	30 days	20.79	7.90
United States	(Chiu *et al.,* 2016)	To test the effects of substituting full-fat for low-fat dairy foods in the DASH diet.	Healthy participants; n=36; aged >21 years old; no anti-hypertensive drugs allowed; male: 21; female: 15.	High Fat DASH Diet which non-fat and low fat dairy product were replace with full fat dairy products for 3 weeks.	3 weeks	3.80	2.20
United States	(Sayer *et al.,* 2015)	To evaluate whether the consumption of lean pork compared with the consumption of chicken and fish as the source of protein in DASH-style diet will affect the blood pressure.	Elevated blood pressure participants; on anti-hypertensive drugs; n=19; age 21 to 75 years old; male: 9; female: 19.	DASH-style diet with chicken and fish as source of protein for 6 weeks.	6 weeks	7.00	6.00

Table 1 continued...

Brazil	(Paula *et al.,* 2015)	To evaluate the effect of the DASH diet associated with increased walking on Ambulatory Blood Pressure Monitoring in type 2 diabetes and uncontrolled hypertension patients.	Type 2 diabetes and hypertension patients; on anti-hypertensive drugs; n=40; male: 18; female: 22.	DASH diet with physical activity such as walking for 15 to 20 minutes per day, 5 days per week.	4 weeks	15.00	9.00
Canada	(Jenkins *et al.,* 2015)	To assess the effect over time on systolic, diastolic and mean arterial pressure, and the relation to sodium, potassium, and portfolio components.	Hyperlipidemia patient; not on anti-hypertensive drugs; n = 241; 20 to 85 years old; male: 93; female (postmenopausal): 148.	Dietary portfolio that included soy protein, viscous fibers and nuts.	24 weeks	2.10	1.80
United States	(Allison *et al.,* 2016)	To determine does the Women's Health Initiative Diet Modification Intervention will result in different rate of incident hypertension and longitudinal changes in blood pressure.	Postmenopausal women; allowed anti-hypertensive drugs; n = 48835; age: 50 to 79 years old.	Low fat diet which allowed total intake of fat 20% / day for 9 years.	9 years	2.74	1.32
United States	(Kirwan *et al.,* 2016)	To evaluate the efficacy of whole grains compared with refined grains on body composition, hypertension and related mediators of cardiovascular disease in overweight and obese adults.	Overweight or obese participants; allow anti-hypertensive drugs; no medication stated; n=40; age <50 years old; male: 6; female 27.	Consume whole grain diet where main cereals used were wheat (57%), rice (21%) and oats (16%).	8 weeks	0.60	5.80
Denmark	(Brader *et al.,* 2014)	To clarify whether a Nordic alternative for a healthy food pattern would have beneficial effects on ambulatory blood pressure in participants with metabolic syndrome.	Overweight to obese participants; allowed anti-hypertensive drugs; n=37; aged 30–65 years old; male: 15; female: 22.	Healthy Nordic diet that contain whole grains, rapeseed oil, berries, fruits, vegetables, fish, nuts and low fat dairy products of Nordic origin.	12 weeks	3.50	4.40
United States	(Dhillon *et al.,* 2016)	To evaluate the effects of consuming almonds as part of an energy-restricted diet on body composition.	Healthy adults participants; not on anti-hypertensive drugs; n=86; aged 18 to 60 years old; male: 21; female: 65.	Consume almond enriched diet.	12 weeks	3.11	1.07
Netherland	(Jonvik *et al.,* 2016)	To assess the impact of taking different nitrate-rich vegetables on subsequent plasma nitrate and nitrite concentration and resting blood pressure in healthy normotensive individuals.	Healthy adult participants; no medication stated; n=22; age 18 to 45 years old; male: 11; female: 7.	Consume 800 mg of nitrate from four different sources.	5 weeks	5.00 to 7.00	4.00 to 8.00

Table 1 continued...

Germany	(Brüll *et al.,* 2015)	To investigate the effects of quercetin after regular intake of blood pressure in overweight to obese participants with pre-hypertension and stage 1 hypertension.	Overweight and obese with pre-hypertension, stage 1 hypertension, hyperlipidemia patients; no medication stated; n=70; age 25 to 65 years old; male: 35; female: 35.	Receive quercetin from onion skin extract powder.	6 weeks	3.60	2.10
United States	(Bressen-dorff *et al.,* 2016)	To study the effect of oral cholecalciferol on arterial stiffness and blood pressure in healthy normotensive adults.	Healthy participants; not on anti-hypertensive drugs n=40; male: 23; female: 17.	Receiving 3000 IU cholecalciferol.	16 weeks	2.50	1.00
United States	(Berry *et al.,* 2016)	To investigate the effects of acute nitrate oxide ingestion on the sub-maximal constant work rate exercise capacity of chronic obstructive pulmonary disease patients.	Chronic obstructive pulmonary disease patients; no medication stated; n=15; male: 12; female: 3.	Dietary nitrate supplementation by using beetroot juice.	1 month	8.00	3.00
United States	(Park *et al.,* 2016)	To test the grape seed extract as a functional ingredient to lower blood pressure in pre-hypertension participants.	Pre-hypertension patients; not on anti-hypertensive drugs; n=36; age 25 to 65 years old; male: 19; female 17.	Give 355ml purified grape seed extract which formulated in fruit based blend of apple, red grape, pomegranate and raspberry juice.	12 weeks	7.00	3.80
United States	(Johnson *et al.,* 2015)	To study the effects of daily blueberry consumption on blood pressure and arterial stiffness in postmenopausal women with pre and stage 1 hypertension.	Healthy postmenopausal women with pre and stage-1 hypertension participants; no medication stated; n=48; age 45 to 65 years old.	Give 22 g freeze-dried blueberry powder.	8 weeks	7.00	5.00
China	(Hou *et al.,* 2018)	To investigate the potential anti-hypertensive effect of whole foxtail millet in mildly hypertensive participants.	Mild hypertension patients; not on anti-hypertensive drugs; n = 45; age 40 to 65 years old; male: 17; female: 28.	50 g of whole foxtail millet diet.	12 weeks	4.13	3.49

SBP: systolic blood pressure; DBP: diastolic blood pressure.

As for the past few decades, excessive intake of sodium had been determined as one of the factors that can contribute to high blood pressure through it renin-aldosterone-angiotensin system mechanism (Donnel *et al*., 2015). In addition, in 2010 the estimated global intake level of sodium consumption was 3950 mg per day which 97.5% has exceeded the WHO recommendation of 2000 mg (Mozaffarin *et al*., 2018; WHO, 2012). Thus, lowering the intake of sodium through salt was beneficial in reducing the blood pressure.

Besides, limiting red meat and processed food intake also shown reduction in both Med diet and DASH diet. According to Wang *et al*. (2008), there is positive association between red meat intake and incidence of hypertension based on the prospective cohort of 28766 females in the United States. In addition, another prospective cohort study among healthy male was associated with increased risk of heart failure (Ashaye *et al*., 2011). The relation between high blood pressure and red meat intake was due to it haem iron and intake of 102.6g of red meat can elevate 1.25 mmHg of SBP. Processed food contains high sodium to preserve the flavour, colour and shape of the food. Large prospective cohort in Spain shows that there was a positive association between the processed food and the hypertension risk (Mendonça *et al*., 2017). The mechanism of how processed food increased the blood pressure was similar to the mechanism of sodium increase the blood pressure.

As dietary portfolio also reduced the blood pressure, it may cause by the intake of the viscous fiber. As stated by Khan *et al*. (2018), the fiber intake will reduce the cholesterol level, body weight and insulin resistance which will also result to reduce the blood pressure. Beta glucan, which is one type of fiber that is known to have protective effect on cardiovascular disease also proved to reduce the blood pressure (Aleixandre & Miguel, 2016). Other than that, low-fat diet that shows reduction in blood pressure may also depends on the type of fat intake. For example, even though low-fat diet can reduce blood pressure but intake of saturated fat from yoghurt had been linked to reduce the blood pressure (Nestel, 2019). Further studies should be done to clear the uncertainty about dietary fat intake.

Next, consuming nuts such as walnuts and almonds reduced the blood pressure through it magnesium content. Magnesium is one of the important minerals that our body needs. It helps to maintain normal nerve and muscle function besides keeping a healthy immune system and a strong bone. Since hypertension occurs when the sodium and potassium ratios become too high, magnesium will possess a pseudo potassium effect that will balance the ratio and regulate a normal blood pressure (Sontia & Touyz, 2007). Other than that, nitrate-rich vegetables intake such as beetroot, salad and spinach does show significant reduction in blood pressure. Nitrate will reduce the blood pressure through it vasodilator nitric oxide mechanism. Even the dietary nitrate supplementation also reduced both SBP and DBP (Kapil *et al*., 2015).

Various dietary supplements had been introduced and was observed for its beneficial effect in reducing blood pressure. Dried blueberries, GSE, onion skin extract powder all have same beneficial effect on reducing blood pressure via quercetin. Quercetin was an antioxidant flavonol that believed to be associated with reduced risk of coronary heart disease and stroke. According to Edwards *et al.* the antihypertensive effect of quercetin helps to reduce blood pressure. Consider as small changes in BP was significant, the quercetin effect should be explored more to helps in understanding on how it mechanism affect the BP since it did not relate with systemic oxidative stress that increase the BP (Edwards *et al*., 2007).

Evidence also showed that cholecalciferol which is one type of vitamin D can reduce the blood pressure. Vitamin D was one of important nutrients that our body needs to function properly. The mechanism of vitamin D reduce the blood pressure was still unclear; however, vitamin D deficiency may lead to high blood pressure. Thus, it is important to take the vitamin D in the suggested amount so it will help in reducing the blood pressure (Jeong *et al*., 2017).

However, there are also risk of bias in this review since there are studies that allowed intake of anti-hypertensive drugs during the intervention (Allison *et al*., 2016; Brader *et al.,* 2013; Kirwan *et al*., 2016; Paula *et al*., 2015; Sayer *et al*., 2015; Storniolo *et al*., 2017; Vitale *et al*., 2018). Other than that, they should consider the gender bias between women and men since men have high risk of developing hypertension compared to women. The risk will be neutral if they include post-menopausal women in the study.

CONCLUSIONS

In conclusion, having a balanced diet and low amount of sodium are effective to reduce the systolic and diastolic blood pressure. Moreover, intake of fruits and vegetables are vital in our daily intake as it helps to reduce blood pressure but also give other nutrients that our body needs to function properly. As dietary factor is one of the modifiable risk factors for hypertension, it should be emphasized globally to prevent the development of cardiovascular disease in the community. Limitation on this review is to confirm the exact dietary pattern since not all

studies stated the details about the dietary intake. Last but not least, further studies on dietary pattern to reduce blood pressure according to the specific community and place should be done since there is biggest difference dietary intake on different country.

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