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The Effect of a Vegan, Plant-Based Diet on Hypertension

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ABSTRACT

Hypertension affects nearly 65 million adults in the United States and is the main risk factor for cardiovascular disease, the current leading cause of death in the U.S. While general recommendations are to increase physical activity and eat a diet low in salt, trans fats, and sugar in order to reduce the risk of hypertension, there is insufficient information on specific diet plans for at-risk patients to follow. In response to this gap in knowledge and the extremely high and steady rates of hypertension and cardiovascular disease throughout the past ninety years, scientists and nutritionists have increased research into different diet options, including the vegan diet, and their effects on heart health. Recent research has found that the inclusion of any animal flesh, and particularly red and processed meats, in a diet is strongly correlated with hypertension. In contrast, fruits and vegetables have high concentrations of antioxidants, minerals, and vitamins, while nuts are low in sodium and high in fiber, unsaturated fatty acids, and antioxidants; all of these factors are known to reduce hypertension. Recent research suggests that the vegan diet, unique in its exclusion of all animal products, offers optimal chemical properties to help reduce the risk of hypertension. Although more research is needed in this emerging field, the evidence compiled so far points to the vegan diet as both a possible preventative solution and a possible treatment plan for the major public health crisis of hypertension and associated heart disease.

INTRODUCTION: A BRIEF OVERVIEW OF HYPERTENSION AND THE VEGAN DIET

Hypertension, more commonly known as high blood pressure, occurs when blood exhibits higher than average pressure on arterial walls ("High blood", 2015). Hypertension is the major cause of cardiovascular disease, which is the leading cause of death in the U.S ("High blood", 2015). High blood pressure can also lead to heart attacks, strokes, blindness, and kidney failure. Known risk factors for hypertension include being overweight, eating a diet high in salt, regular smoking and drinking, and lack of physical activity. People of low socioeconomic status as well as minority populations, especially African Americans and Mexican Americans, are disproportionately affected by hypertension (Grotto, Huerta, & Sharabi, 2008). This is believed to be due to genetic predispositions as well as obstacles to providing early and consistent treatment to these populations (Douglas et al., 2003). To prevent and control hypertension, the Food and Drug Administration recommends consuming less sodium and exercising more often in order to lose weight ("High blood", 2015).

Along with lifestyle choices, a contributory cause of hypertension includes the genetics of an individual that may predispose them for high blood pressure. Certain alleles have been selected for through evolution that favor survival under nutritional hardship. However, these alleles predispose cardiovascular disease when calorie intake is in excess. Many of the genes that are strongly associated with hypertension have been identified, including a chloride channel, an angiotensin II receptor-associated protein, and a gene involved in steroid biosynthesis (Nicoll & Henein, 2010). Genetic predisposition for hypertension can originate not only from DNA sequences, but also from epigenetic modifications, which can be affected by an individual's diet or the health behaviors of the mother while the fetus is in utero (Ordovás & Smith, 2010). This means that nutrition can have lasting effects on the ability of the body to maintain a healthy blood pressure. If a pregnant mother smokes, is overly-stressed, or experiences famine while pregnant, epigenetic changes can occur to help the fetus survive, but may leave the individual ill-prepared to cope with plentiful calorie intake later in life, leading to hypertension. Changes in gene expression can also directly affect kidney fluid and salt balances, the renin-angiotensin-aldosterone system (which produces hormones that regulate blood pressure), the sympathetic nervous system's ability to regulate blood pressure, and blood vessel function and structure ("Causes of", 2015). Thus, in

addition to the direct effects of diet on health, through epigenetics, the diet of an individual can be a significant factor of their health, especially blood pressure.

Cardiovascular disease has remained the leading cause of death in the U.S. for the past ninety years, demonstrating that prevention and treatment methods have not yet been successful in significantly reducing the vast mortality and morbidity caused by heart disease (Neyer et al., 2007). However, diet has been identified as a major contributor to these diseases, making food intake an important area of study in the search for possible interventions. Scientists have long acknowledged the negative effects of red meat on cardiovascular health (Schwingshackl et al., 2017), and have recently begun researching other animal proteins and animal products in an effort to find a diet and lifestyle solution to the hypertension and cardiovascular disease epidemics.

Many scientists have begun to explore the health effects of a solely plant-based, or vegan, diet. Vegans do not consume animal flesh, eggs, or dairy products and therefore differ from both omnivores and ovo-lacto vegetarians ("Cholesterol and", n.d.). Cholesterol, which deposits in arteries and contributes to raised blood pressure by narrowing blood vessels, is produced only in animals, and is thus found in all animal products but in no plant-based foods ("Cholesterol and", n.d.). Without animal products as a diet staple, vegans tend to eat more fruits, vegetables, seeds, legumes, and nuts than both ovo-lacto vegetarians and omnivores (Craig, 2009). These foods act as replacements for animal products for vegans, fulfilling caloric and nutritional needs, and are thus consumed in greater quantity by vegans than omnivores (Larsson & Johansson, 2005).

The aim of this literature review is to summarize available information on the most recent findings on a vegan, plant-based diet and its effects on hypertension. A plant-based diet provides a possible mode of intervention for hypertension, and in turn may reduce rates of heart disease. This review includes information on common components of a vegan diet, the health benefits of these components, and findings on the impact of consumption of animal products on human health.

VEGANISM: THE UNIQUE EXCLUSION OF ALL ANIMAL PROTEIN

While many diets have been studied and eventually recommended for a general healthy lifestyle and to reduce hypertension specifically, the vegan diet is distinct in its total exclusion of animal products. The vegan diet differs from some of the most widely-recommended diets for hypertension, including the Mediterranean diet and the Dietary Approach to Stop Hypertension (DASH) diet, both of which are composed primarily of fruits, vegetables, nuts, whole grains, and low-fat animal products (Mayo Clinic Staff, 2017; LeLong et al., 2017). While the vegan diet is also composed of many of the same components considered to be heart-healthy, such as fruits and nuts, the vegan diet differs from the Mediterranean diet and DASH diet, as these other diet options allow for the intake of animal protein. Animal protein is found not only in meat, but in all animal products, including eggs and dairy products. Lean meats and low-fat dairy products are usually considered to be part of a "healthy" diet and are included in many hypertension diet recommendations (LeLong et al., 2017). As this paper exclusively focuses on the vegan diet, the effects of animal products considered "healthy" options in other diets will be specifically singled out and addressed.

Because the vegan diet excludes all animal products, it offers a unique area of study and allows researchers to focus on the impact of the animal protein component of diet specifically, while still taking into account the major foods of the vegan diet, such as fruits and nuts. A recent study published in 2017 examined the effects of a variety of nutritional components, including protein type, on blood pressure (LeLong et al., 2017). Researchers organized participants into groups based on the amount of each type (animal and plant) protein that the individuals consumed. Significantly, the study found that while the risk of hypertension increased by 26% for animal protein intake, the risk of hypertension was reduced by 15% for plant protein intake, with no association found between total protein intake and hypertension (LeLong et al., 2017). These results demonstrate promising implications for further research into abstaining from consumption of all animal products as a means to prevent and treat hypertension.

NEGATIVE EFFECTS OF ANIMAL FLESH ON HYPERTENSION

The inclusion of meat, especially red meat, in a diet has been found to be associated with hypertension. While red meat has been shown to have the largest effect, animal flesh of any kind has been associated with increased risk of high blood pressure, although some results are controversial. When risk factors and protective factors of hypertension were held constant to avoid confounding variables, a 2016 study found that long-term consumption of any animal flesh greater than or equal to one serving per day was associated with an increased risk of hypertension (pooled hazard ratio of 1.30), as compared to those whose consumption of meat was less than one serving per month (Borgi et al., 2015). This study included independent consumption of either red meat, poultry, or seafood, and found that intake of each flesh-type was independently associated with increased hypertension risk. These findings demonstrate that even animal proteins considered lean and healthy meats may have a negative impact on cardiovascular health. The authors noted that the specific biochemical mechanisms by which

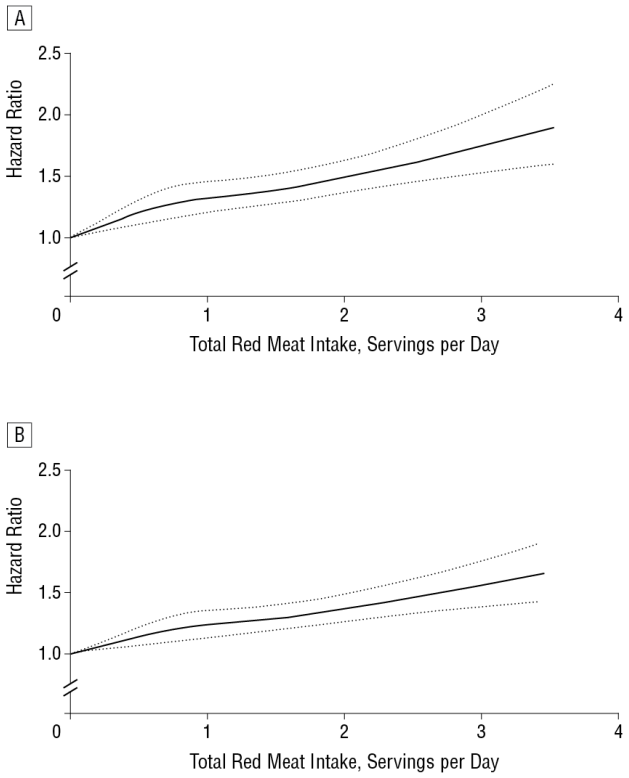

FIGURE 1. *Total red meat intake is positively associated with higher hazard ratios of all-risk mortality. The figure above shows the dose-response relationship between red meat intake and risk of all-cause mortality in a health professionals follow-up study (A) and a nurses' health study (B). The results were adjusted for age; body mass; alcohol consumption; physical activity level; smoking status; race; menopausal status and hormone use in women; family history of diabetes mellitus, myocardial infarction, or cancer; history of diabetes mellitus, hypertension, or hypercholesterolemia; and intakes of total energy, whole grains, fruits, and vegetables, all in quintiles. 95% confidence intervals are represented by the dotted lines. lines represent 95% CI (Pan et al., 2012).*

animal flesh of any kind affects hypertension remain somewhat unknown and controversial (Borgi et al., 2015). Red meat and processed meat have consistently shown especially strong, positive associations with high risks of hypertension. In a 2017 study, high levels of red meat intake, defined in this study as greater than 200 grams per day, were found to increase the risk of hypertension significantly, as shown in Figure 1 (Schwingshackl et al., 2017). These results were consistent across sex, short-term and long-term time frames, and in small and large sample sizes. The effects of processed meat were also evaluated in this study, and it was found that an increased intake of processed meat by about 30 grams per day increased the risk of hypertension by about 7%. This study highlights red meat and processed meats, both of which are excluded from the vegan diet, as high risk factors of hypertension (Schwingshackl et al., 2017).

While researchers continue to study the effect of a variety of animal protein types on hypertension, the current findings strongly suggest an association between animal flesh consumption and high risk of hypertension.

THE OMISSION OF DAIRY AND EGGS FROM THE VEGAN DIET

The omission of dairy and eggs from the vegan diet has been found to lower cholesterol levels in vegans compared to humans who consume animal products. Cholesterol deposits in arteries contribute to hypertension because the buildup of cholesterol plaque narrows blood vessels, increasing the buildup of pressure on blood vessel walls ("What is high", 2018). In a 2014 study, researchers aimed to compare high density lipoprotein-cholesterol (HDL-C), a known contributor to hypertension, among vegans, ovo-lacto vegetarians, and omnivores (Huang et al., 2014). The study analyzed lipid serum profiles of a large sample of women of varying ages and found that vegans had lower levels of HDL-C than ovo-lacto vegetarians, who had even lower levels of HDL-C than omnivores (Huang et al., 2014). These findings suggest that cholesterol levels fall as consumption of animal products decreases: from inclusion of eggs and dairy in ovo-lacto vegetarian diets to exclusion of meat, eggs, and dairy in vegans. Thus, following a vegan diet tends to be associated with having lower levels of hypertension-causing cholesterol.

VEGAN CONSUMPTION OF FRUITS AND VEGETABLES PROVIDES BENEFICIAL ANTIOXIDANTS AND VITAMINS

Vegans tend to eat more fruits and vegetables than non-vegans because produce is substituted for meat, dairy, and eggs (Alonso et al., 2004). Many studies have found a positive association between fruit and vegetable intake and reduced risk of hypertension. For example, a study conducted in 2004 within a Mediterranean population found that among those with high vegetable-fat consumption (about 37% of all energy intake on

average), those who consumed large amounts of fruits and vegetables had significantly fewer occurrences of hypertension than those whose diet did not include many fruits or vegetables. This study suggests that this association may be due to the high levels of potassium and antioxidants in both fruits and vegetables, which may account for the fact that fruits and vegetables help to combat hypertension even in people consuming relatively high concentrations of fat (Alonso et al., 2004). Although the mechanisms by which potassium and antioxidants reduce hypertension are not fully understood, some possible methods are through central sympatholytic and insulin-sensitizing actions (Ando et al., 2010). Similarly, a 2016 study involving U.S. men and women found that both short-term and long-term increased consumption of whole fruits significantly reduced the risk of hypertension (Borgi et al., 2016). While no association between increased vegetable intake and lowered risk of hypertension was found in this specific study, the study's results mentioned that this was likely due to the cooking techniques often involved with preparing vegetables, such as the use of salt (Borgi et al., 2016). In general, key nutritional components of the vegan diet provided by fruits and vegetables result in lower concentrations of blood cholesterol, lower blood pressure, and higher levels of fiber, folic acid, antioxidants, and phytochemicals, and (Craig, 2009).

VEGAN CONSUMPTION OF NUTS GENERALLY LOWERS RISK OF HYPERTENSION

Along with fruits and vegetables, nuts are a main component of the common vegan diet. As nuts provide some of the highest caloric concentrations among plant-based foods, vegan diets often include ample amounts of nuts and nut products in order to fulfill caloric needs (Djoussé, Rudich, & Gaziano, 2009). Many studies have shown that regular nut consumption has been associated with lower risk of hypertension. An epidemiological study in 2009 found that regular nut consumption resulted in a lower risk of hypertension in a population of lean adult men. The study attributed this benefit of nuts to the fact that nuts are low in sodium and high in fiber, unsaturated fatty acids, and antioxidants, all of which are known to reduce hypertension (Djoussé et al., 2009). In a more recent study conducted in 2015, above average nut consumption was found to lower blood pressure, with pistachios having the biggest effect on the reduction in hypertension (Mohammadifard et al., 2015). The study also found that almonds, walnuts, cashews, mixed nuts, and peanuts had a positive, although small, effect on reducing blood pressure. The findings of both the 2015 and 2009 studies involving tree nuts demonstrate a positive association between nut consumption and lowered rates of hypertension.

NUTRIENT CONTENT DIFFERENCES: A FOCUS ON POLYPHENOLS

Intake of vitamin, nutrient, and other molecular contents, including polyphenols, differ between individuals following a vegan diet and those who do not follow a vegan diet. Polyphenols are naturally occurring antioxidants of plants and are found in many common fruits, vegetables, and beverages (Pandey & Rizvi, 2009). Foods that are the most rich in polyphenols include grapes, apples, pears, cherries, berries, wine, tea, coffee, cereals, legumes, and chocolate (Pandey & Rizvi, 2009). A 2016 study found that, compared to other diets, the vegan diet is associated with higher levels of polyphenols such as genistein and daidzein (Elorinne et al., 2016). These high levels of polyphenols found in those following a vegan diet have been associated with lower risks of hypertension, as shown in Figure 2. Furthermore, the results of a study in Brazil suggest that increased intake of polyphenols has positive effects on reducing hypertension (Miranda, Steluti, Fisberg, & Marchioni, 2016). The main sources of polyphenols in this study were dietary, with the most polyphenols being contributed by fruit and coffee (Miranda et al., 2016). Another study compared the effects of the presence or absence of polyphenols in olive oil consumed by young women with higher than average blood pressure and early hypertension. The results suggest a strong relationship between consumption of a diet containing polyphenol-rich olive oil and a fall in blood pressure (Moreno-Luna et al., 2012). Not only is olive oil a common substitute for butter in vegan diets, but additionally, fruits and vegetables, both of which are consumed in high amounts by vegans, contain high concentrations of polyphenols (Moreno-Luna et al., 2012). Polyphenols, which have been found in higher levels in those following a vegan diet, were demonstrated to lower the risk of hypertension, as well as to protect against the development of other chronic diseases, such as cardiovascular diseases, diabetes, and cancer.

CONCLUSION AND APPLICATION

Recent and ongoing research largely supports the idea that a vegan, plant-based diet composed primarily of fruits, vegetables, and nuts significantly reduces the risk of hypertension. Not only does this diet provide optimal concentrations of vitamins and nutrients for healthy blood pressure, but it also excludes foods rich in animal proteins, harmful fats, and cholesterol. Animal products contain animal protein, saturated fats, and cholesterol, which clog arteries and weaken the body's lipid-metabolism system, contributing to hypertension. With high levels of hypertension, individuals are at much higher risk for heart disease — the leading cause of morbidity and mortality in the U.S. today.

While a strong association between a vegan diet and

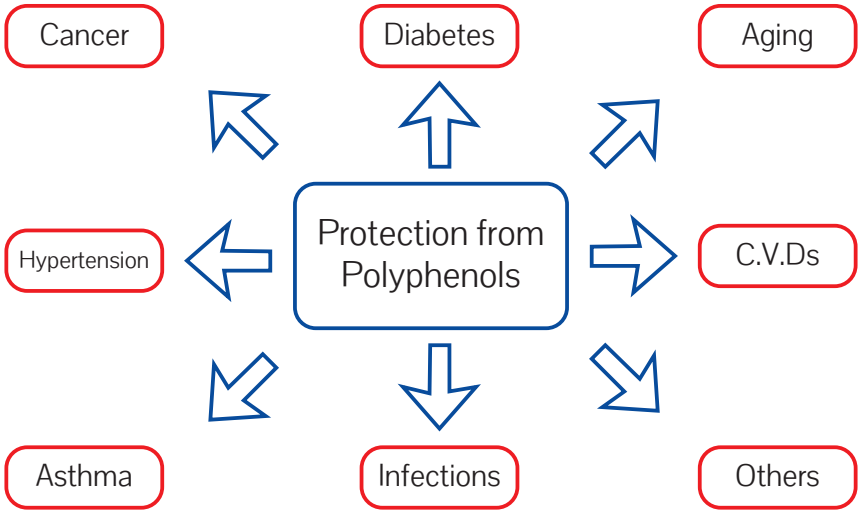

FIGURE 2. *Polyphenols are naturally occurring compounds found largely in the fruits, vegetables, cereals and beverages. Epidemiological studies of polyphenols have demonstrated that they provide significant protection against development of several chronic diseases, including cardiovascular diseases (CVDs), cancer, diabetes, infections, aging, asthma etc. (Pandey & Rizvi, 2009).*

low rates of hypertension has been demonstrated in many studies, additional research is necessary in order to gain a more holistic view of the effects of a vegan diet. Very few studies have focused on the effect of protein type (animal vs. non-animal), monounsaturated fatty acids (found in foods such as olive oil, nuts, and avocados), and omega-3 polyunsaturated fatty acids (found in fish, but also in vegan-friendly foods such as flaxseed, tofu, and walnuts) on hypertension (Appel, 2003). The few studies that have examined these molecules have found that they display a possible correlation with blood pressure, but more research is needed to support any claims (Appel, 2003). For example, a recent study found that high intake of omega-3 fatty acids reduced blood pressure in individuals receiving no other treatment for hypertension (Saremi & Arora, 2009). While the correlation between omega-3 fatty acids and lower risk of hypertension was significant (ranging from a 20% to a 33% reduction in cardiovascular disease caused mortality), the dose necessary to reduce blood pressure in an individual was very high, at about five servings of fish per week (Saremi & Arora, 2009). Additionally, a 2016 study examined the effect of animal protein versus plant protein on mortality in humans (Song et al., 2016). The study found a positive association between high animal protein intake and cardiovascular disease and mortality; additionally, it identified an inverse relationship between high plant protein intake and all-cause mortality and cardiovascular mortality, especially in individuals with at least one lifestyle risk factor, such as smoking. These findings suggest that protein type has a substantial effect on cardiovascular health, to which blood pressure is a major contributor. The study also notes that plant protein, unlike animal protein, has been linked to lower levels of hypertension and lower incidence of cardiovascular disease. Importantly, the study stresses that additional research is necessary to better understand the effect that dietary protein source has on human health, specifically cardiovascular health (Song et al., 2016).

Based on a growing body of evidence, there is substantial evidence that a vegan diet, unique because of its total exclusion of animal products, can prevent or reduce hypertension. With the prevalence of hypertension and cardiovascular disease on the rise, researchers should continue to prioritize these studies of plant-based diets in an effort to more fully understand possible lifestyle interventions that the public can exercise to increase their overall health. While these interventions may be effective in improving health outcomes, they may be difficult to implement, especially in the populations that could most benefit from them. Public health programs with a focus on diet face challenges of adoption, cultural practices that must be respected, and socioeconomic barriers, both physical and financial. Nevertheless, more research should be done, especially in the epidemiological field, in order to produce effective, evidence-based, and culturally appropriate interventions that stress the benefits of implementing more plant-based foods into the diets of at-risk Americans.

While a variety of medications aimed at treating the symptoms of hypertension do exist, no permanent solution has yet been identified ("Types of", 2017). Because of this, more effort should be put toward lifestyle interventions, such as diet changes, that serve

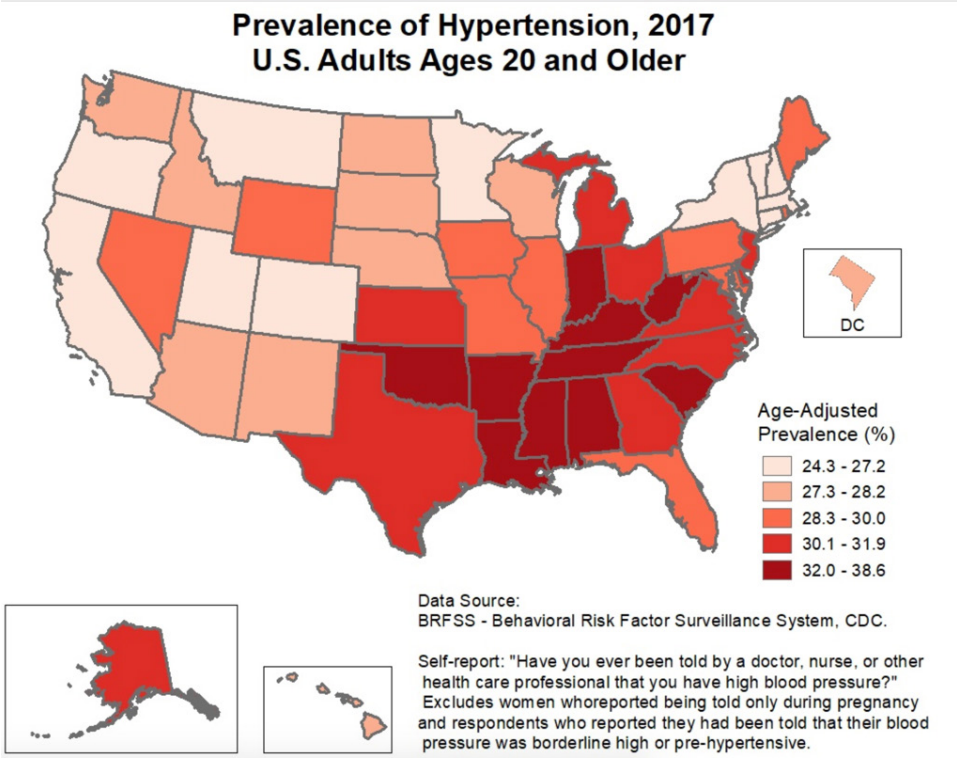

FIGURE 3. *Self-reported prevalence of hypertension among U.S. adults ("High blood", 2017).*

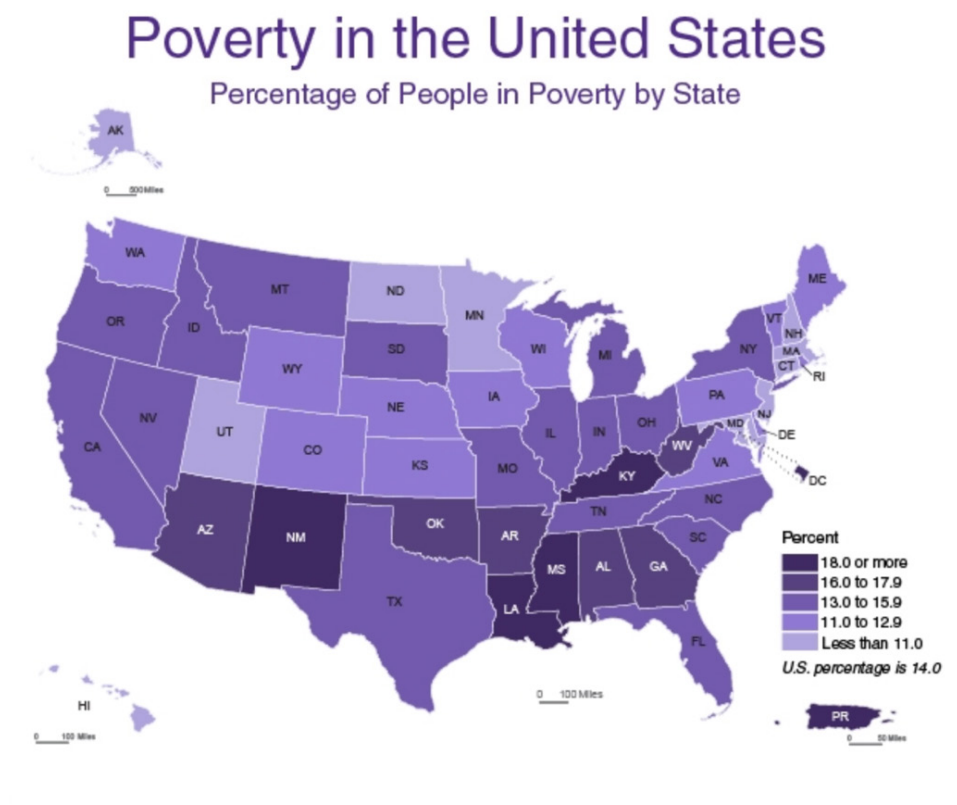

FIGURE 4. *The percentage of people in poverty in the U.S. by state based on the 2016 U.S. census ("Poverty", 2017).*

to both prevent hypertension and reduce blood pressure. Reducing blood pressure in those already diagnosed with hypertension improves quality of life and reduces the risk of cardiovascular complications. Additionally, many people are faced with barriers when attempting to receive medication due to complications of affordability, accessibility, and acceptability within a community.

Lifestyle changes, such as diet, may prove to be more effective in treating hypertension than medication since medication only combats the symptoms of hypertension, while nutrition acts as both a preventative and a treatment measure (Khatib et al., 2014). Additionally, lifestyle changes offer a more inclusive approach because they are more cost-effective and accessible to a wider range of socioeconomic statuses; additionally, they allow the individual to take control of their own situation rather than relying on a system they do not trust (Khatib et al., 2014). Taking this into consideration, to appropriately treat the most at-risk populations, culturally-sensitive and financially appropriate interventions are needed (Grotto, Huerta, & Sharabi, 2008).

As shown in Figures 3 and 4, states with the highest rates of adult hypertension, such as Louisiana and Mississippi, also experience the highest rates of poverty. The coexistence of these conditions presents unique challenges to implementing more plant-based diets in these states, as processed foods, most of which contain animal products, are often the cheapest food options ("Facts", 2017). Many people of low socioeconomic status do not have proper availability to unprocessed foods due to the fact that processed foods are often cheaper to produce, transport, and distribute. In addition, living in a food desert – areas that are located more than a mile away from a supermarket – can be a significant barrier to accessing fresh fruits and vegetables. Over seven percent of Americans live in food deserts ("Facts", 2017). However, despite the challenges of low socioeconomic status that many Americans face, lifestyle changes, including diet, are necessary in order to prevent the hypertension rates from increasing.

Many studies have shown the success of lifestyle change, specifically involving nutrition, on reducing the risk of hypertension (LeLong et al., 2017). One example, the DASH diet, has been shown to significantly reduce hypertension in many studies. However, an equal amount of studies involving the DASH diet demonstrated no association with reduced risk of hypertension. Because of these inconsistencies among studies, the effectiveness of various diet recommendations continues to be researched for modifications in nutrition to further improve results in hypertension (LeLong et al., 2017).

The vegan diet, unique because of its entire exclusion of animal products, is one diet that is just beginning to be researched for its effects on hypertension. With hypertension as a risk factor for cardiovascular disease, a major contributor to morbidity and the leading cause of mortality in the U.S., an intervention aimed at reducing hypertension rates also has potential to improve population health on a national scale.

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