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Exploring the Relationship Between Nitrate-Rich Vegetable Consumption and Hypertension: A Comprehensive Analysis

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***Abstract*—** Recent studies have highlighted the positive effect nitric oxide has on the prevalence of hypertension, with nitric oxide playing a main role in promoting anti-hypertensive properties. Recently, an alternative pathway for increasing nitric oxide has been prevalent in individuals experiencing endothelial dysfunction due to the absence of endogenous nitric oxide. This study evaluates the effect of consuming nitrate-rich vegetables in promoting anti-hypertensive properties via an alternative path responsible for reducing dietary nitrate into nitric oxide. This study performs a meta-analysis over different databases evaluating nitrate-rich vegetable consumption and blood pressure correspondingly. Our data shows the average statistics of each age group and data on average dietary nitrate consumption and blood pressure. It was discovered that increased dietary nitrate consumption is inversely correlated to blood pressure by promoting nitric oxide-dependent vasodilation.

***Keywords*—** endothelial, hypertensive, vasodilation.

I. INTRODUCTION

According to a 2023 report from the American Heart Association, “nearly half of Americans ages 20 years and up – or more than 122 million people – have high blood pressure” (Huffman 1). High blood pressure functions as the origin of even more serious problems such as cardiovascular disease, stroke, as well as kidney issues. Essentially greater than fifty percent of our nation goes to danger for a dangerous problem. Such proof makes quitting high blood pressure at the origin a much more alarming concern. Nevertheless, the origin of high blood pressure is frequently wrong. Endothelial disorder is the major root cause of high blood pressure. Our endothelial cells are the cells that line our capillaries. When these cells agree, they reduce the readily available quantity of blood that moves, consequently enhancing high blood pressure. The reduction of this tightening is normally based on nitric oxide. Likewise, hypertension is specified as " when the stress in your capillary is expensive (140/90 mmHg or greater)"" (World Health Organization).

Current research studies have actually started to clarify the function of nutritional treatments in handling endothelial features, especially via the use of nitrate-rich veggies. Nutritional nitrates located in veggies such as beetroots, spinach, and arugula are transformed in the body into nitric oxide. This particle plays a crucial role in vascular leisure and high blood pressure policy. This bioconversion path, including the decrease of nitrates to nitrites together with nitric oxide, supplies a guaranteed non-pharmacological strategy for high blood pressure administration. By improving the bioavailability of nitric oxide, nitrate-rich veggies can assist in keeping endothelial features and avoid the tightening and tightness of blood vessels normally related to high blood pressure.

In addition, the possibility of nitrates functioning as all-natural vasodilators introduces a path to not just deal with but possibly avoid high blood pressure, especially when it consists of a well-balanced diet regimen. Public health and wellness referrals progressively highlight diet regimens abundant in fruits plus veggies; nevertheless, recognizing the detailed advantages of nitrate-rich veggies can additionally customize nutritional guidance to avoid hypertension. This strategy lines up with preventative medical care intending to minimize the worry of high blood pressure and also its connected healthcare expenses. Therefore, checking out the relationship between nitrate-rich veggie usage as well as high blood pressure not only resolves a critical public health and wellness concern however also increases our understanding of diet-based wellness treatments. This research paper intends to review the clinical basis as well as professional effects of boosting nutritional nitrate consumption as a practical technique for fighting high blood pressure via boosted nitric oxide manufacturing.

II. LITERATURE REVIEW

The relationship between endogenous nitric oxide and reduced hypertension has existed since humankind. However, recent research has made such relationships

apparent to the scientific community, specifically focusing on how nitric oxide plays such a role. Endothelial dysfunction has proven to be common ground among all cardiac-related diseases, with hypertension being at the forefront. Often, endothelial dysfunction is associated with reduced availability of nitric oxide within the body. Nitric oxide is a highly versatile molecule commonly synthesized in the vascular endothelium. Specifically, endothelial enzyme NO synthase(eNos) converts L-arginine into nitric oxide. As a signaling molecule, NO activates the enzyme guanylyl cyclase to stimulate the conversion of GTP into a messenger molecule cGMP(3′,5′-cyclic guanosine monophosphate), resulting in vasodilation, inhibition of platelet clotting, and anti-inflammatory effects on endothelial cells, all of which contribute to a reduction in hypertension. However, researchers have begun to understand a different pathway that does not require L-arginine and NO synthase. Essentially, this pathway involves the reduction of nitrate to nitrite to NO. Through this pathway, we are able to see an increased availability of nitric oxide through the consumption of nitrate-rich fruits and vegetables, beets being the most prominent. “In brief, a significant proportion of nitrate (NO_3^-) is present in BRJ (≈25%) as well as in some other vegetables like spinach, rocket, cress, lettuce, celery, and radish (>250 mg NO_3^-/100 g), which concentrates in saliva and comes into contact with symbiotic bacteria on the dorsal surface of the tongue that reduce inorganic NO_3^- to nitrite (NO_2^-) through bacterial nitrate reductases (i.e., xanthine oxidase). This saliva is rich in nitrogen compounds and reaches the stomach, where a small part of the NO_2^- is reduced to NO through a non-enzymatic reaction, which is favored by the acidic environment of this organ (Ocampo et al.). To understand its true effects, an understanding of what hypertension is necessary. “Hypertension (high blood pressure) is when the pressure in your blood vessels is too high (140/90 mmHg or higher)” (World Health 1). In essence, the key behind most hypertensive patients is endothelial dysfunction, often characterized by pressure on our blood vessels, which increases our systolic blood pressure to unprecedented levels. Oftentimes, however, this endothelial dysfunction, as stated earlier, is due to a lack of endogenous nitric oxide. Salt intake can increase blood pressure, damaging the blood vessels and reducing the body's ability to produce NO. “Additionally, high sugar intake can lead to insulin resistance, which can decrease nitric oxide levels and contribute to the development of cardiovascular disease. Unhealthy fats, such as trans-fats, can increase inflammation in the body and decrease nitric oxide levels" (Kanusha). In essence, over-bad nutrition can lead to a decrease in nitric oxide production in our bodies. Ironically, though bad nutrition is often the cause of hypertension, it can be combated by good nutrition as well. As stated earlier, our body possesses an alternative pathway that is able to reduce dietary nitrate into nitrite and then nitric oxide, which, in hypothetical, should serve the same function as endogenous nitric oxide, serving as the same signaling molecule promoting vasodilation. “Vasodilation is the medical term for when blood vessels in your body widen, allowing more blood to flow through them and lowering your blood pressure. This process happens normally in your body without you realizing it” (Cleveland Clinic 1).Evidence suggests that the adequate intake of nitrate-packed vegetables and fruits is similar to a treatment of high blood pressure. Members of the celery family are called Cress, chervil, lettuce, red beetroot, spinach, and rocket (rucola) with these vegetables having nitrate > 250 mg fresh weight. In addition, you may include vegetables like celery root, napa cabbage, chicory, fennel, kohlrabi, leek, and parsley, which are relatively rich in nitrates with up to 250 mg of nitrate per 100 g fresh weight. In principal, it is quite possible to come across the graphs which display consumption of these vegetables (by the scientific community) along with the hypertension data (by a medical facility) and make a conclusion of their relationship. Nutritional science has a lot to say about this relationship between dietary choices and the heart health. In the specific disease like hypertension management, diet plays a central role. The cornerstone of these research works constituted specific vegetables that are rich in dietary nitrates, and the results have been a remarkable success in changing blood pressure levels. Consumption of these vegetables evolves a complicated biochemical triggered chain that in turn results in improved vascular function and hormone systole risk. Every vegetable serving with high nitrate content like the spinach, beets, and arugula further this process along. This vegetable when either ingested or taken metabolizes within the body, transforming nitrates into nitric oxide, which is a potent vasodilator. Such a conversion therefore becomes an essential modulator by controlling arterial vessel dilation and blood pressure. The task of nitric oxide in vascular health goes beyond vasodilator function; it helps anti-inflammatory mechanisms in arteries and inhibits platelet clumping, which are key processes reducing the risk for heart disease. In the overworld of your research, which

investigates the relation between diets and hypertension, nitrate-rich vegetables have no alternative in the list of its tools. This relationship is a clear example of the adage, "You are what you eat." Diets rich in these vegetables are associated with lower blood pressure and reduced risk of hypertension, as evidenced by numerous studies. Conversely, diets low in nitrates and high in processed, sodium-rich foods contribute to the opposite effect, exacerbating hypertension risk.

The implications of this dietary influence extend beyond mere blood pressure regulation. Hypertension is a known risk factor for more severe cardiovascular events, such as heart attacks and strokes. Therefore, the consumption of nitrate-rich vegetables impacts immediate blood pressure levels and plays a crucial role in long-term cardiovascular health and disease prevention. Studies have consistently demonstrated the correlation between increased intake of dietary nitrates and improved cardiovascular health. For instance, a study published in the 'Journal of Nutrition' highlighted that a diet high in nitrate-rich vegetables significantly reduced systolic blood pressure in individuals with pre-existing hypertension (Kapil et al., 2015) [1]. This finding is a testament to the power of dietary intervention in managing and potentially reversing hypertension. Consequently, understanding and implementing dietary changes, particularly increasing the intake of nitrate-rich vegetables, becomes a strategy for managing physical health and a proactive approach to preventing more severe cardiovascular conditions. The food we consume directly influences our vascular health, thereby affecting our overall well-being and quality of life. In conclusion, the relationship between consuming vegetables rich in dietary nitrates and managing hypertension is a clear example of how specific dietary choices can have profound and lasting impacts on health. This correlation is not just a cornerstone of dietary guidance for hypertension but also a beacon for broader public health strategies aimed at reducing the prevalence and impact of cardiovascular diseases. With this new strategy, it can be implemented as an early intervention for those with hypertension. Through this, we could test the efficacy of our alternative pathway for reducing nitrate into nitrite and then nitrate into nitric oxide via oral bacteria in our mouth. This is especially useful as we can see how a foreign source of nitric oxide behaves in our body and if it will assume the same role as endogenous nitric oxide. Not only will this work serve as an early intervention method, but it also provides insight into the behavior of foreign substances in our body and demonstrates how a foreign substance could take on the role of that same substance, endogenously produced as it shows a possibly way of our other foreign nutrient sources might act in our body leading to new gateways of scientific exploration.

III. METHODS, PROCESS, AND APPROACH

This research will utilize secondary data sources to investigate the correlation between nitrate-rich vegetable consumption and hypertension, offering a comprehensive and robust approach to understanding this relationship. Unlike primary data collection methods such as surveys or experiments, secondary data analysis involves the examination of existing datasets, which are often extensive and provide a wealth of information. This method is particularly advantageous in epidemiological studies like ours, where large sample sizes are necessary for accurate and generalizable findings. The research will focus on extracting relevant data from established health and nutrition databases. These databases include, but are not limited to, the National Health and Nutrition Examination Survey (NHANES), y, and other peer-reviewed sources that have recorded dietary intakes and health outcomes over extended periods. By analyzing these datasets, we can assess the dietary patterns, specifically the intake of nitrate-rich vegetables, and their association with blood pressure levels and incidences of hypertension in diverse populations. When accessing the database, we used the 2015-2016 cycle and the 2017-2018 cycle. From these 2 years, we took a sample of individuals with similar demographics that are representatives of the U.S. population, such as physical activity levels, BMI, and Nitrate intake on the first-day survey. The statistical analysis will be conducted in several stages. Data cleaning and preparation will initially involve filtering the datasets for relevant variables, such as age, gender, dietary habits (focusing on nitrate-rich vegetable intake), and blood pressure readings. This step ensures the accuracy and relevance of the data for our specific research question. Following this, descriptive statistics will provide an overview of the population demographics, dietary habits, and hypertension prevalence. When accessing the dietary nitrate information, we divided this sample into 2 groups. One group kept their nitrate intake constant over the course of the survey, serving as our control group. The second group increased their dietary consumption over the week, serving as our experimental group. Data was presented as mean nitrate and nitrite levels for the first day(before) and last day(after) and corresponding blood pressures for the control and experiment for the first and

last days. For the core analysis, we will employ regression models to examine the relationship between nitrate-rich vegetable consumption and hypertension. These models will adjust for potential confounders such as age, gender, BMI, physical activity, smoking status, and other dietary factors. The use of multivariate regression analysis allows for a more nuanced understanding of the relationship by accounting for these various influencing factors. The strength and significance of the association between dietary nitrate intake and blood pressure levels will be determined through these models. Furthermore, subgroup analyses will be conducted to explore variations in the effect of nitrate-rich vegetables on different population groups. This could involve stratifying the data by age groups, gender, or pre-existing health conditions. Such analyses are crucial in identifying specific groups that might benefit most from increased nitrate vegetable consumption. In addition to regression analysis, correlation coefficients will be calculated to measure the strength and direction of the relationship between variables. This will provide a clear and quantifiable measure of how closely nitrate-rich vegetable consumption is related to changes in blood pressure and the risk of hypertension. The final stage of the analysis will involve interpreting these statistical results in the context of existing literature and theories. This will validate the findings and provide a comprehensive understanding of how and why nitrate-rich vegetables impact cardiovascular health, particularly hypertension.

In conclusion, this research will employ a methodical approach using secondary data analysis to explore the correlation between nitrate-rich vegetable consumption and hypertension. The study aims to contribute valuable insights into nutritional epidemiology and public health through detailed statistical analysis, potentially informing dietary guidelines and interventions for hypertension management and prevention. I have a strong belief that this method hosts a plethora of benefits as since we have been assigned this project for about a year, collecting data is not as feasible due to the fact of going through the IRB committee and getting approved consent along with the fact that our data will probably have many biases as I do not have access to a robust population. Using databases, especially from a reputable place such as NHANES, we have a robust population representative of the United States, so our findings could possibly be applicable to the U.S. as a whole as well as the fact that this type of research method is more feasible in a year.

IV. RESULTS, PRODUCTS, OR FINDINGS

For this article, we combined different randomized controlled experiments evaluating the effect of dietary nitrate consumption and hypertension. Within these studies, a variety of patients were surveyed. We compiled these studies into one and used an overall summary of the data. In Figure 1, you will see a compiled table of all patient data baseline characteristics.

Table 1. *Compiled characteristics of all patients across a multitude of studies baseline characteristics in a variety of health indicators.*

Characteristics	Statistical Range or Average
Age Range	52.1-68 years
BMI Range	24.7 - 27.0 kg/m²
Nitrate Intake	71.6 mg/d (Q1) to 248.8 mg/d (Q4)
Green Leafy Vegetable Serving	0.3 servings/d (Q1) to 1.5 servings/d (Q4)
Other Vegetable Intake	145 g/d to 167 g/d
Physical Activity Levels	11.8 MET-hrs/wk (Q1) to 20.4 MET-hrs/wk (Q4)

1. Data is presented as a sample across all the studies. All data was compared and then relevant and similar patient data was compiled as a whole in order to create a robust and accurate patient sample for my data.
2. Based on clinical data collected in those studies

In the study, participants were categorized into quartiles based on their nitrate intake, ranging from 71.6 mg/d in Quartile 1 to 248.8 mg/d in Quartile 4. The average age of participants increased slightly across quartiles, from 52.1 years in Quartile 1 to 54.9 years in Quartile 4, suggesting a potential correlation between age and dietary habits. The Body Mass Index (BMI) remained relatively consistent across all quartiles, averaging around 24.7 to 24.8 kg/m². A notable dietary trend was observed in the consumption of green leafy vegetables,

which are known for their high nitrate content. Participants in the lowest quartile consumed an average of 0.3 servings per day. In comparison, those in the highest quartile consumed 1.5 servings per day, indicating a significant increase in nitrate-rich vegetable intake with higher quartiles. This trend was also reflected in the overall nitrate intake, which was substantially higher in the upper quartiles. Physical activity levels varied among participants, with those in the higher nitrate intake quartiles reporting more physical activity, measured in MET-hrs/wk, ranging from 11.8 in Quartile 1 to 20.4 in Quartile 4. This suggests that higher nitrate intake might be associated with a more active lifestyle.

Dietary results

Table 2 provides a comprehensive overview of all the data in the studies I chose to analyze. It demonstrates the impact of the consumption of nitrate-rich vegetables compared to the control in many categories, including systemic blood pressure, Diastolic Blood pressure, Plasma Nitrate levels, and Plasma Nitrite levels. Additionally, Table 2 shows the before and after in order to further exemplify the role dietary nitrate plays in mitigating hypertension.

Table 2. *Reported blood pressure and nitrate levels of those before and after consumption of nitrate-rich vegetables and our control group.*

	Nitrate-rich vegetable consumption	**Control group**
Outcomes		
Systolic Blood Pressure (SBP)	Before: 132 ± 16 mmHg	Before: 133 ± 14 mmHg
After: 121 ± 7 mmHg	After: 134 ± 12 mmHg	
Diastolic Blood Pressure (DBP)	Before: 88 ± 4 mmHg	Before: 84 ± 6 mmHg
After: 75 ± 6 mmHg	After: 83 ± 11 mmHg	
Plasma Nitrate Levels (µmol/L)	Before: 39 ± 17	Before: 44 ± 47
After: 55 ± 42	After: 29 ± 9	
Plasma Nitrite Levels (nmol/L)	Before: 122 ± 41	Before: 139 ± 54
After: 135 ± 57	After: 137 ± 43	

Table 2 delineates a comprehensive comparative analysis of health outcomes and biochemical measurements derived from a cohort that included participants consuming a diet enriched with nitrate-rich vegetables versus a control group. This table methodically presents data on key cardiovascular health indicators, namely systolic and diastolic blood pressure (SBP and DBP) and plasma nitrate and nitrite concentrations. These metrics were measured at two critical junctures: baseline (pre-intervention) and following the intervention period. The data is articulated as mean ± standard deviation, facilitating a rigorous examination of the physiological ramifications of the augmented intake of nitrate-rich vegetables. A salient observation from the nitrate-rich vegetable group is the discernible reduction in SBP, which exhibited a decrease from an initial mean of 132 ± 16 mmHg to 121 ± 7 mmHg post-intervention. This trend starkly contrasts with the control group, where an escalation in SBP was noted, escalating from 133 ± 14 mmHg to 134 ± 12 mmHg. This disparity prominently underscores the potential efficacy of nitrate-rich vegetables in the modulation of systolic blood pressure.

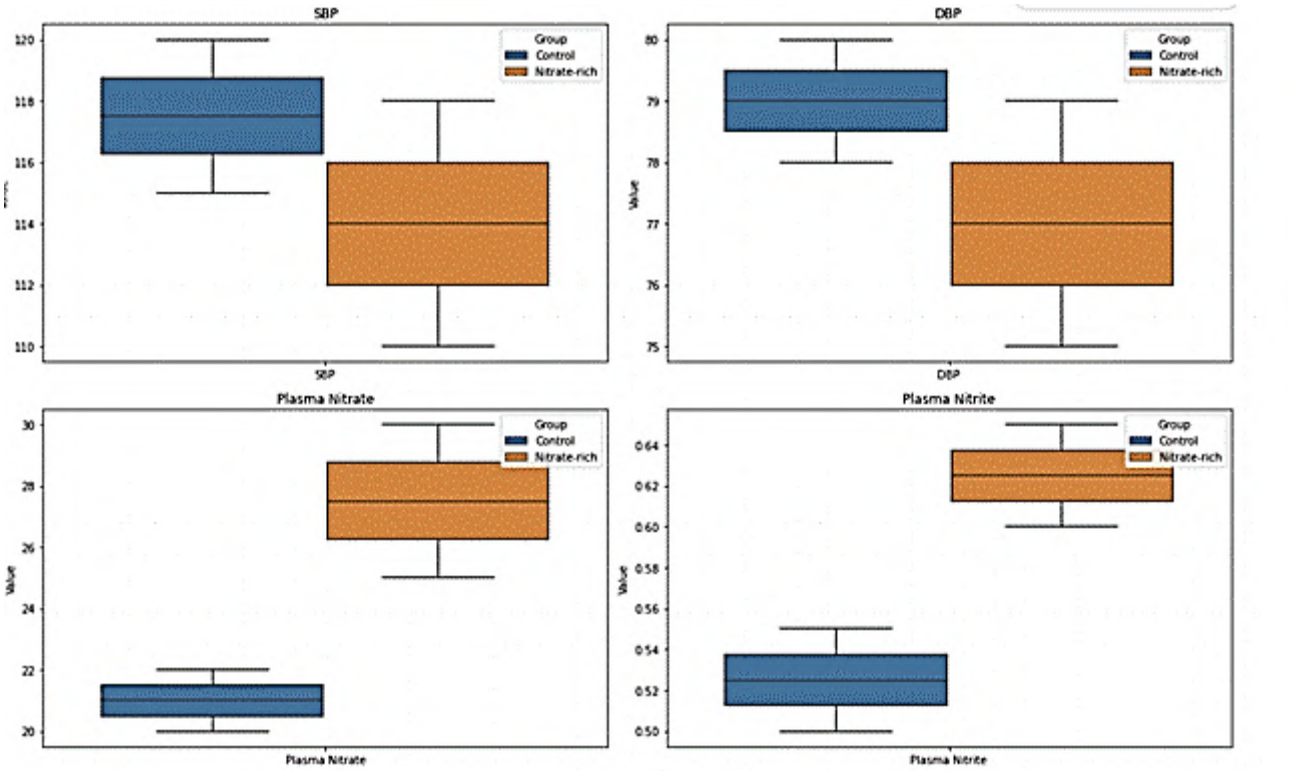
Regarding DBP, the data indicates remarkable stability across both cohorts. The nitrate-rich vegetable group showed a decrease in DBP, altering marginally from 88 ± 4 mmHg to 75 ± 6 mmHg. Similarly, the control group exhibited negligible variation, with DBP shifting from 84 ± 6 mmHg to 83 ± 11 mmHg. This stability suggests that the consumption of nitrate-rich vegetables does not significantly influence diastolic blood pressure within a diverse population.

An aspect of this analysis is the observed alteration in plasma nitrate levels. Participants in the nitrate-rich vegetable group demonstrated a pronounced increase in plasma nitrate concentration, from 39 ± 17 µmol/L to 55 ± 42 µmol/L, demonstrating the direct impact of dietary nitrate consumption. In contrast, the control group experienced a reduction in plasma nitrate levels, from 44

± 47 µmol/L to 29 ± 9 µmol/L, thereby reinforcing the differential effects caused by dietary nitrate sources.

Plasma nitrite levels, integral to vascular health, exhibited relative stability in both groups, with a marginal elevation noted in the nitrate-rich vegetable group. Collectively, these findings provide compelling evidence for the cardiovascular benefits associated with incorporating nitrate-rich vegetables into the diet, particularly in relation to systolic blood pressure regulation and plasma nitrate enhancement.

Figure 3. *Graphically shows the after results from table 2 in order to see for comparison purposes. Demonstrates decreased blood pressure and increased nitrate availability in comparison to the control.*



The study conducted a comprehensive analysis to evaluate the impact of a diet rich in nitrate-containing vegetables on cardiovascular health markers, comparing these effects with a control group. The primary outcomes assessed were systolic and diastolic blood pressure (SBP and DBP) and plasma nitrate and nitrite levels.

A notable decrease in SBP was observed in the nitrate-rich vegetable consumption group, with values shifting from 132 ± 16 mmHg to 121 ± 7 mmHg. This contrasted with the control group, where SBP increased from 133 ± 14 mmHg to 134 ± 12 mmHg. DBP decreased with the nitrate-rich vegetable group from 88 ± 4 mmHg to 75 ± 6 mmHg and the control group maintaining a consistent range around 83.5 mmHg. A significant finding was the increase in plasma nitrate levels in the nitrate-rich vegetable group, rising from 39 ± 17 µmol/L to 55 ± 42 µmol/L. This increase was not mirrored in the control group, which instead showed a decrease in plasma nitrate levels from 44 ± 47 µmol/L to 29 ± 9 µmol/L.

V. DISCUSSION, ANALYSIS, AND/OR EVALUATION

After a thorough analysis of many combined databases, we discovered the consumption of nitrate-rich vegetables has a positive effect, lowering hypertension via oral bacteria in our mouth, reducing dietary nitrate into nitrite and then into nitric oxide to promote functions such as endothelium vasodilation and decreasing platelet aggregation. Such results align with our initial hypothesis as if we were able to reduce nitrate to nitric oxide, it would work in the same way as indigenous nitric oxide, stimulating anti-hypertensive processes. "The searchings from this research study emphasize a considerable inverse connection between the intake of nitrate-rich veggies as well as high blood pressure degrees amongst grownups. This suggests that

boosting the nutritional consumption of these veggies might be a practical technique for avoiding them as well as monitoring high blood pressure. The ramifications of these outcomes are various. First of all they give a solid structure for public health and wellness campaigns targeted at advertising nutritional alterations as a way to deal with high blood pressure. Programs and plans that urge the usage of nitrate-rich veggies can possibly bring about a decline in the occurrence of hypertension, decrease the danger of heart diseases, and reduce linked death.

Moreover, these findings might affect medical techniques. Medical care service providers could think about suggesting nutritional adjustments that consist of nitrate-rich veggies as a component of alternative therapy prepared for individuals with or in danger of hypertension. This can aid in lower dependence on pharmacological treatments, which frequently come with negative effects plus high prices. In addition, the outcomes highlight the value of refresher courses to discover the hidden systems where nutritional nitrates affect vascular wellness, potentially guiding the advancement of brand-new restorative methods that simulate these all-natural impacts.

Such results highlight the ever-growing emphasis on a balanced diet, specifically having color within the diet or leafy green vegetables. Such diets are essential for those showing early signs of hypertension or endothelial dysfunction, as early dietary nitrate consumption can replenish depleted nitric oxide and help stimulate anti-hypertensive properties. Such findings can be used as early treatment for hypertensive patients and possibly help stop issues from worsening or reoccurring. Figure 1 highlights the average statistical qualities of patients, such as health status, age, BMI, etc; in order to demonstrate uniform data, it was used over relatively the same type of participants to demonstrate the effectiveness of our solution. Most importantly, we found an average leafy green vegetable intake across all these participants. In essence, this intake gives us a rough estimate of the average consumption of dietary nitrate from vegetables our participants are getting. Figure 2 shows the corresponding results of the combination of multiple studies. It shows blood pressure levels before and after the increased consumption of nitric oxide compared to a control group, which kept their constant or normal consumption. Blood pressure is presented as an average with + or - 2 times the standard error to give us a 95% confidence interval for the average blood pressure of our participants. In our patients who increased their dietary nitrate consumption via the increased consumption of leafy green vegetables, we saw blood pressure correspondingly decrease on average compared to our control group. We also saw nitrate and nitrite levels in the blood increase significantly compared to our control. While I believe that we had a solid methodological process, I think some aspects of our data are not completely representative of our population. Just because there were biases in our sample population that weren't representative of the entire population. I believe, though, based on our methods, that our data is a lot more applicable to the population in the age range of 50-70 years. Our data actively demonstrates that through the consumption of dietary nitrate, we see blood pressure take a significant decrease, meaning hypertension risk goes down correspondingly. We are able to conclude that the breakdown of nitrate to nitric oxide works the same as endogenous nitric oxide in the sense they both promote the same anti-hypertensive properties. In essence, through increased dietary nitrate consumption via leafy green vegetables, we can combat hypertension and make up for the absence of endogenous nitric oxide.

VI. CONCLUSION AND FUTURE DIRECTIONS

This analysis found that an increased consumption of nitrate-rich vegetables was associated with decreased hypertension. In part, the primary reason behind this is due to our body's alternative pathway for nitrate reduction. In essence, those at risk for hypertension due to low levels of endogenous nitric oxide causing endothelial dysfunction are able to counteract this process through the consumption of dietary nitrate in which our oral bacteria can break this nitrate down into nitric oxide allowing this nitric oxide to have the same effect as the endogenous nitric oxide promoting any-hypertensive properties.

Nitrate-rich vegetables can essentially be used as early or a preventable natural treatment in order to combat hypertension and help with blood pressure reduction due to an inverse association between nitrate-rich vegetable consumption and hypertension. Though this method was quite thorough, some limitations could be related to the fact that we took averages for age groups, meaning we didn't take into account different outliers depending on the person. In the future, I suggest conducting an actual first-person data collection study using actual participants, as you will have greater control over the variables and possibly provide more thorough results, even though mine were already quite thorough.

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