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Effects of Dietary Sodium Restriction on Blood Pressure and Cardiovascular Disease Outcome: A Review

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Abstract- The effect of reduction of dietary sodium intake on blood pressure has been an important topic for discussion among physicians and researchers. In the past decades, the contribution of excessive sodium intake as a risk factor for developing cardiovascular diseases has remained controversial. The objective of this manuscript was to evaluate current epidemiological studies in order to determine what effects have been observed on the blood pressure of individuals with modest reduction of dietary sodium intake and what impact this dietary modification might have on the future of cardiovascular diseases. The search strategy was based on PubMed/MEDLINE database in order to gather information on the testing hypothesis, which is that a modest reduction of dietary sodium intake has no adverse effects on health and reduces the risk of developing future cardiovascular diseases in both normotensive and hypertensive adults. The search was not limited to the country of origin, however it was limited to only peer-reviewed publications written in English. The result of this review reveals that the majority of the current studies and public guidelines support giving 5-6 g of salt/day for lowering blood pressure in both normotensive and hypertensive adults in order to lower the risk of developing non-communicable diseases, including cardiovascular disease. In conclusion, the data collected from systematic reviews, randomized control clinical trials and prospective studies all suggest that modest reduction of dietary sodium intake has a positive outcome in lowering the risk of developing cardiovascular diseases and attenuating difficulties in both normotensive and hypertensive adult population. Word Count: 250

Key Words- Dietary Sodium Intake, Blood Pressure, Cardiovascular Disease, Hypertensive, Normotensive

I.INTRODUCTION

Hypertension is becoming a major health issue around the globe, and it is considered the leading risk factor for cardiovascular disease with estimated contribution of 49% of all coronary heart disease and 62% of all stroke[8], [12]. In 2012, cardiovascular disease accounted for an estimate of 17.5 million deaths, this value represents 31% of all the deaths around the world[12]. Clinical trials have shown reducing blood pressure through various pharmacological interventions lowers the incidence and mortality rate of cardiovascular diseases such as: stroke, MI and CHF. [1] . However, with the aging population and rate of obesity increasing due to poor dietary habits and the lack of physical activities, incidence of hypertension is on the rise unless preventive measures are taken seriously [8] . Important risk factors for hypertension include [11] :

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● Age: The risks are higher in the elderly.
● Race: More common amongst the black populations.
● Family history: Genetics plays a major role in the development of hypertension.
● Being overweight or obese and not being physically active: More volume of blood is needed to supply oxygen to the tissues, the more weight an individual has. The pressure 4 5 on the artery walls increases as the volume of blood circulating the blood vessels increases, leading to hypertension.
● Smoking tobacco: Chemicals in tobacco can damage and narrow the arterial wall lining, leading to hypertension.
● Excess of dietary sodium: The amount of sodium we intake daily controls the osmotic pressure applied against the blood vessels' interior lining by changing the balance of electrolytes and fluid in the blood. There will be more fluid in the blood, since kidneys have to eliminate less urine to balance the excess sodium, thus raising the blood pressure. Although, there are a number of different factors that may contribute to causing raised blood pressure as discussed earlier, the importance of dietary sodium in the regulation of blood pressure has received much attention over the past few years; however, this area of research has been controversial for several reasons. The major difficulty in synthesizing an accurate conclusion between salt and blood pressure is that the biochemistry pathways of salt metabolism, and its physiological effects on hypertension, are extremely complex[7] .

Also, after decades of research, many scientific studies have been published on the relationship between salt and hypertension, with conflicting and contradictory results. Does everybody need to restrict their salt intake? Or do only the salt sensitive individuals need to regulate their salt consumption? The objective of this manuscript is to review the current literature relating the effect of modest sodium intake compared with higher sodium intake on blood pressure, and its potential health benefits in reducing the risk of cardiovascular disease events in both normotensive and 5 6 hypertensive individuals.

II. METHODS

The search strategy was based on retrieving appropriate articles through PubMed/MEDLINE, Cochrane library and Google Scholar. The title and abstract of the research articles were the primary tools in selecting the appropriate publications and the reference list of the articles were reviewed to find more related articles. Furthermore, the search terms used were: "dietary sodium reduction", "systolic and diastolic blood pressure", "cardiovascular diseases", "vascular diseases", "hypertensive/normotensive", "cardiovascular disease mortality". The general results of the research is located in the appendix found in (Table 2). A number of textbooks were used in order to provide detailed knowledge with regards to basic cardiovascular physiology and pathology with treatment guidelines for hypertension and cardiovascular diseases. The inclusion criteria for this manuscript was to only include peer-reviewed published studies from the year 2005 to present day. The only exception was made for meta-analyses of systematic reviews which relied on earlier studies. The main emphasis was to find research studies that were based on large sample-size randomized control trials, systematic reviews of the literature and prospective studies. All studies had to include normotensive and hypetensive patients on trials longer than one month period.

The use of urine biomarkers or 24-hour urinary sodium excretion monitors had to be included in all studies to estimate the patients sodium intake. Lastly, there were no limitations in selecting articles with regards to the country of origin. Exclusion criteria included published articles dated before the year 2005 with the exception mentioned earlier. Articles that were not a published peer-reviewed journal were excluded from the search. Furthermore, articles having trials with period of less than one month and any articles 6 7 with references to the use of pharmacological interventions were omitted. Once published articles were chosen and filtered to meet the criteria of this manuscript, an evidence

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table (located in the appendix) was created in order to evaluate each article with corresponding level of evidence. Results The results of the analysis of many studies all support the working hypothesis, which is: modest reduction of dietary sodium intake has no adverse effects on health and reduces the risk of developing future cardiovascular diseases in both normotensive and hypertensive adults [2], [3], [4], [7], [9], [10], [11], [12]. The results of studies that link salt to hypertension will be discussed first followed by the studies that link hypertension to cardiovascular diseases. One of the strongest sets of evidence linking salt to hypertension comes from a series of studies called DASH, for "Dietary Approaches to Stop Hypertension." A study by Sacks et al. examined data on DASH-Sodium trial for the effect of reduction of dietary sodium intake on blood pressure [10] . The DASH-trial and a control trial representing a diet of a typical North American were studied within hypertensive vs. normotensive patients based on race, gender, BMI, age and three sodium intake levels: high (3500 mg), modest (2300 mg) and low (1100 mg) for one month period. The results of subgroups of (high vs. modest) sodium intake demonstrated a fall of systolic pressure by 2.1 mmHg ($P < 0.001$) for total stroke and HR=1.42 (95% CI: 1.20, 1.69; P for trend < 0.001) for total CVD mortality.

III.DISCUSSION

The importance of dietary sodium reduction and the impact it carries on health has received much attention over the past decades. There is a wide consensus that excess dietary sodium may be harmful through a number of mechanisms that increase blood pressure and perhaps, through mechanisms unrelated to increased blood pressure[6] .

For example, Dr. Umesawa reported that people with high sodium intake can develop cardiovascular problems despite having normal blood pressure measurements and body weight[11] . Therefore, it should be noted that, the results of Dr. Umesawa study along with the analysis of the results of other studies all support the working hypothesis, which is to say modest reduction of dietary sodium intake has no adverse effects on health and reduces the risk of developing future cardiovascular diseases in both normotensive and hypertensive adults. On the other hand, however, few researchers studying the connection between salt and health say salt has been unfairly penalized. They propose that high salt consumption does not raise blood pressure in most of us, but will for a fraction of salt-sensitive people[5] . Saltsensitivity is defined as the difference of at least 10% in mean arterial pressure after a low sodium intake (9 mmol/day or 0.5g of salt/day) and also, after a high sodium intake (249 11 12 mmol/day or 14g of salt/day)[5] . Furthermore, other publications have shown that salt reduction needs to be within a certain dietary limit. For example, Dr. He[6] found that as long as the total dietary salt intake is kept at 5-6g/day, there should be no significant adverse effect on blood concentrations of: triglyceride, epinephrine, norepinephrine, dopamine, nor a change in renal activity. However, crossing the limit may cause potential harm, a five gram increase in salt intake, for instance, was related to a significant increase in the relative risk for both stroke and CVD as represented in (Figure 1)[2] .

Although, the in depth analysis of the papers reviewed for this manuscript overwhelmingly points to the consensus that excess dietary sodium would likely lead to increased blood pressure as well as an increased in cardiovascular disease morbidity and mortality, the limitations of this paper point to the consensus amongst researchers that salt metabolism, and its effects on hypertension, are extremely complex. Also, it is difficult to know who is sensitive to sodium, as there is not an easy test for sodium sensitivity. Therefore, there are significant debates over whether everyone can benefit from eating a lower-sodium diet, as lowering sodium intake does not reduce blood pressure in all people with hypertension. What is known so far is that there is a well-made connection between high sodium intake (>5g/day) and cardiovascular diseases with no indications that reasonable sodium intake grounds any harm[6],[7],[12] . Challenges should be accomplished to reduce sodium intake in

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populations with high consumption of sodium, by directing the main foundations of additional sodium in the diet (e.g. processed food and fast food restaurants). Emphasis on daily recommendation of salt intake should be embedded within the general public with healthy dietary practices, such as increasing the consumption of fruits and vegetables etc. Moreover, a reasonable lessening in salt intake has other benefits on human health, such as: lowering the risk of certain cancers i.e. stomach, a straight outcome on stroke, and lowering the risk of renal stones[6] . 12 13 Conclusion The evidence and data from the various studies stated in this report, support the conclusion that a modest reduction of daily sodium intake can lower blood pressure and benefit both the normotensive and the hypertensive population. Additionally, lowering blood pressure through the means of reducing sodium intake could substantially decrease the rate of cardiovascular event mortality. Although, current recommendation to reduce salt intake to 5-6 g/day would be effective, however maintaining a healthy life-style through consuming fruits, vegetables, attaining the daily vitamins and minerals, with moderate exercise and modest sodium intake would be ideal. 13 14 Appendix Tables/Figures Figure 1 [2] Relative risk of stroke and total cardiovascular disease related to increase salt consumption of 5g/day.

Table 1 [9] Estimated reduction in cardiovascular events based on a dietary reduction of sodium to 1840mg/day in Canada.

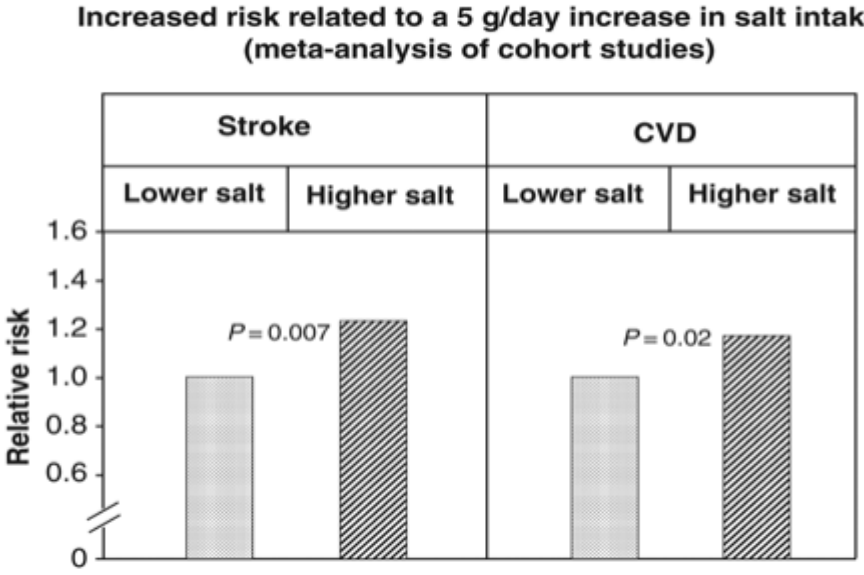

Table 2 Summary of Study Designs Reviewed.

Event	Number of events in 2005	Occurrence	Total preventable events (n)	Events prevented (n)
AMI	76,878	70% in hypertensives	53,891	3185
		30% in normotensives	22,987	521
Stroke	47,373	84% in hypertensives	39,793	5790
		16% in normotensives	7580	423
Heart failure	9488	91% in hypertensives	8634	1571
		9% in normotensives	854	60
Total	133,739		133,739	11,550

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Table 2 Summary of Study Designs Reviewed

Study Design	# of Studies
Systematic review	3
RCT	2
Prospective Longitudinal Cohort Study	3

Table 3 Evidence Table

First Author	Year of publication	Study Design	Level of Evidence	Study Population	Outcome/Results
Sacks, FM	2004	RCT	1	n = 412	The results of subgroups of (high vs. modest) sodium intake demonstrated a fall of systolic pressure by 2.1 mmHg (P<0.001)in the control group, and a fall of 1.3 mm Hg (P=0.03) in the DASH trial. In the subgroups of (modest vs. low) sodium intake a greater fall of 4.6 mmHg (P<0.001) was found in the control group and 1.7 mmHg in the DASH trial (P<0.01).

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WHO	2012	Systematic Review	1	N/A	Higher sodium intake was associated with higher risk of stroke and coronary heart disease. Reducing sodium to less than 2000 mg/day was more beneficial and had no adverse effect on blood lipids and catecholamine concentrations.
Cook, NR	2005	Prospective Longitudinal Cohort Study	3	Sodium-reduced group (n=581) Control group (n=576).	Significant dose-response trend between the change in blood pressure and the urinary sodium excretion were found. Estimated systolic blood pressure fall for 100 mmol/day reduction in sodium intake at 18 and 36 months were 7.0 and 3.6 mmHg respectively, after systematic error was corrected.
He, FJ	2013	RCT	1	Normotensive (n= 2220) Hypertensive (n= 734)	A modest reduction of salt intake (5-6 g/day) significantly lowered the systolic/diastolic blood pressure of hypertensive individuals by 5/3 mmHg and by 2/1 mmHg in normotensive individuals. Additionally, there was no adverse effect on blood lipids and catecholamine concentrations.
Penz, ED	2008	Systematic Review	1	N/A	Reducing sodium intake to a moderate

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					level of 1840 mg/day was predicted to decrease 11, 550 CVD events/year.
Cappuccio, FP	2009	Systematic Review	1	n = 177 025	Higher level of sodium intake was associated with a greater risk for stroke (RR 1.23, P=0.007) and cardiovascular disease (RR 1.14, P= 0.07). There was no evidence of publication bias.
Cook, NR	2007	Prospective Longitudinal Cohort Study	3	Pre-hypertensive (n=3126)	The low-sodium group had a 25% decrease risk of cardiovascular event compared to the control group (RR=0.75, P=0.04).
Umesawa, MH	2008	Prospective Longitudinal Cohort Study	3	n = 58,730 (23,119 men and 35,611 women)	Sodium intake positively affected the mortality rate for total CVD and stroke. Multivariable hazard ratios were strongest with the highest compared to the lowest category of sodium intake.

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