AN ABSTRACT OF THE THESIS OF

Ki Sung Kang for the Degree of Master of Science in Environmental Health Management presented on August 29, 1990.

Title: The Effects of Using a Cation Exchange Water Softener on Blood Pressure

Abstract approved: Redacted for Privacy
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Water in 70 percent of the cities in the United States is hard enough that softening is either required or recommended. It is estimated that approximately 30 percent of all homes in the United States use water softeners. Water softeners, the cation exchange types suited for residential use, exchange sodium for the calcium and magnesium in water. The increase in sodium levels in the softened water caused by cation exchange softening is a direct function of the hardness level of the untreated water. For people who use groundwater, which has a relatively high level of naturally occurring sodium, magnesium and calcium, the additional sodium from cation exchange water softeners may create health hazards for the general population and could adversely affect those who are sensitive to salt or on low sodium diets. To prevent potential health hazards for the general population, no consumption of softened water by cation

exchange water softeners should be recommended. If soft water is needed for some practical reasons, a "Separate Water Line System" should be recommended for homeowners.

The Effects of Using a Cation Exchange Water Softener on Blood Pressure

by

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A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed August 29, 1990

Commencement June 1991

APPROVED:

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Date thesis presented August 29, 1990

Typed by Sadie's Word Processing for Ki Sung Kang

ACKNOWLEDGEMENTS

I wish to express my deep appreciation to Dr. Annette M. Rossignol, my major professor, for her interest, encouragement and guidance during my coursework and the preparation of this thesis.

I want to extend my thanks to Dr. David W. Phelps and Dr. Dawn Peters for serving on my graduate committee and reviewing the manuscript.

Appreciation is extended to the Public Health Department of Oregon State University.

I am deeply grateful to my mother for her financial support, and to my wife Jung and my sons Gabriel, and Michael, whose endless patience and love supported me throughout my graduate work.

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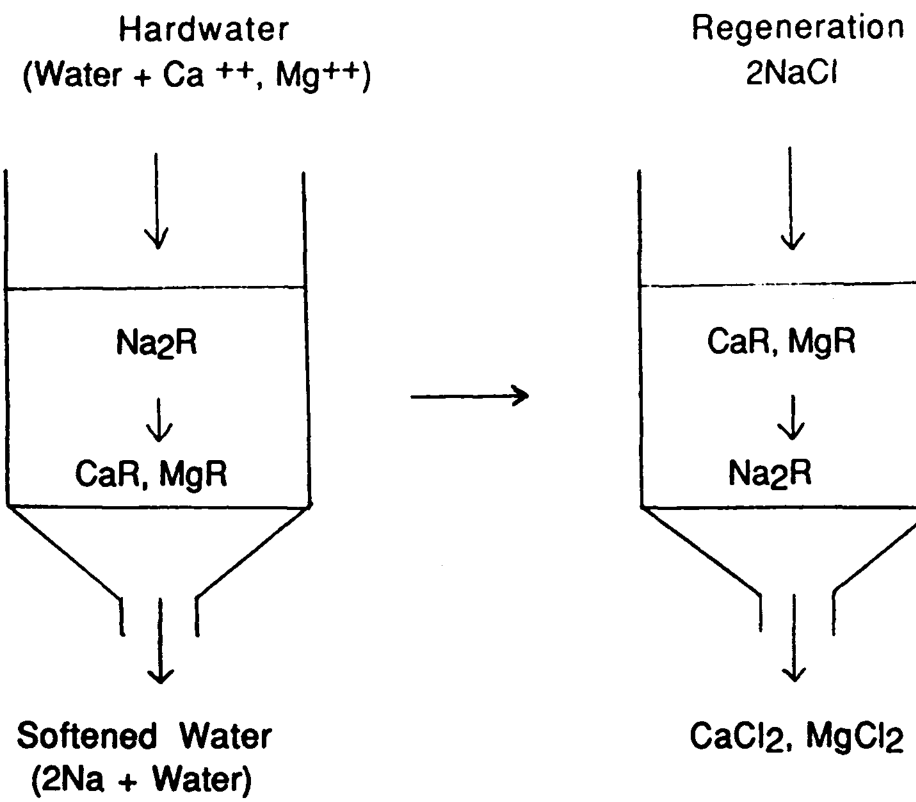
Chapter 1

INTRODUCTION

Homes which are using well water tend to use water softeners. Until now there are no statistical reports showing percentages of homes that have water softeners. It is estimated that approximately 30 percent of all homes in the United States use water softeners [1]. Most residential water softeners, the cation exchange types, exchange sodium for the calcium and magnesium in water. The water softeners add 8 mg/L of sodium for 17.1 mg/L (1 grain/gallon) of hardness removed (Figure 1). Hardness is primarily due to the presence of ions of calcium and magnesium and is expressed as the equivalent quantity of calcium carbonate ($CaCo_3$). Water with less than 75 mg $CaCO_3$/liter is considered soft and above 75 mg/liter as hard. The harder the water, the greater the use of water softeners.

Weinsier found higher incidence of hypertension in people with higher sodium intake [2,3]. Additionally, Tuthill found that higher blood pressure among school children who consumed water with higher sodium levels or water from a home water softener [4]. However, Pomrehn et al. found no such relationship in children [5]. For people who use groundwater, which has a relatively high



$Ca^{++} + Na_2R^{*} \rightarrow CaR + 2Na$

$Mg^{++} + Na_2R \rightarrow MgR + 2Na$

$CaR + 2NaCl \rightarrow Na_2R + CaCl_2$

$MgR + 2NaCl \rightarrow Na_2R + MgCl_2$

R* : (Cation Exchange Resins)

8 mg/L of sodium added for 17.1 mg/L (1 gr/gl) or hardness removed

Figure 1. Mechanism of Cation Exchange Water Softeners

level of naturally occurred sodium, magnesium and calcium, the additional sodium from water softeners may create health hazards.

Sodium levels less than 20 mg/L, are recommended by the American Heart Association (AHA) for patients with cardiac or renal diseases. Where water supplies contain more than 20 mg/L, a dietary sodium recommendation of less than 1.0 g/day is difficult to maintain. In a survey of 2,100 water supplies, covering approximately 50% of the population of the United States, White et al., found that about 42% of municipal water supply samples are unsatisfactory for use with diets that strictly limit sodium [6].

In addition to adding sodium to the water, cation water softeners remove calcium and magnesium from the water [7]. Increased calcium intake has been shown to decrease blood pressure in people [8]. In this way, removal of calcium from water may have adverse health effects on a population. Hypomagnesemia occurs in alcoholics, persons performing hard labor in hot climates, patients with heart failure, and those using diuretics [9]. Hard water provides a small amount of magnesium. For people who have heart disease and those using diuretics, this contribution from water is important. Using cation exchange water softeners that add more sodium and remove calcium and magnesium ions, may be hazardous to one's health. Most people believe that water softeners remove impurities from the groundwater and drinking such softened water is good for their health. However, there is no evidence to support the consumption of softened water for health reasons.

I want to define "Separate Water Line System" in this paper as the following (Figure 2): The line from groundwater which supplies the drinking and cooking water bypasses the softener (unsoftened water in cold water line). Other lines for bathing and laundering are connected to the softener (softened water in the hot water line only).

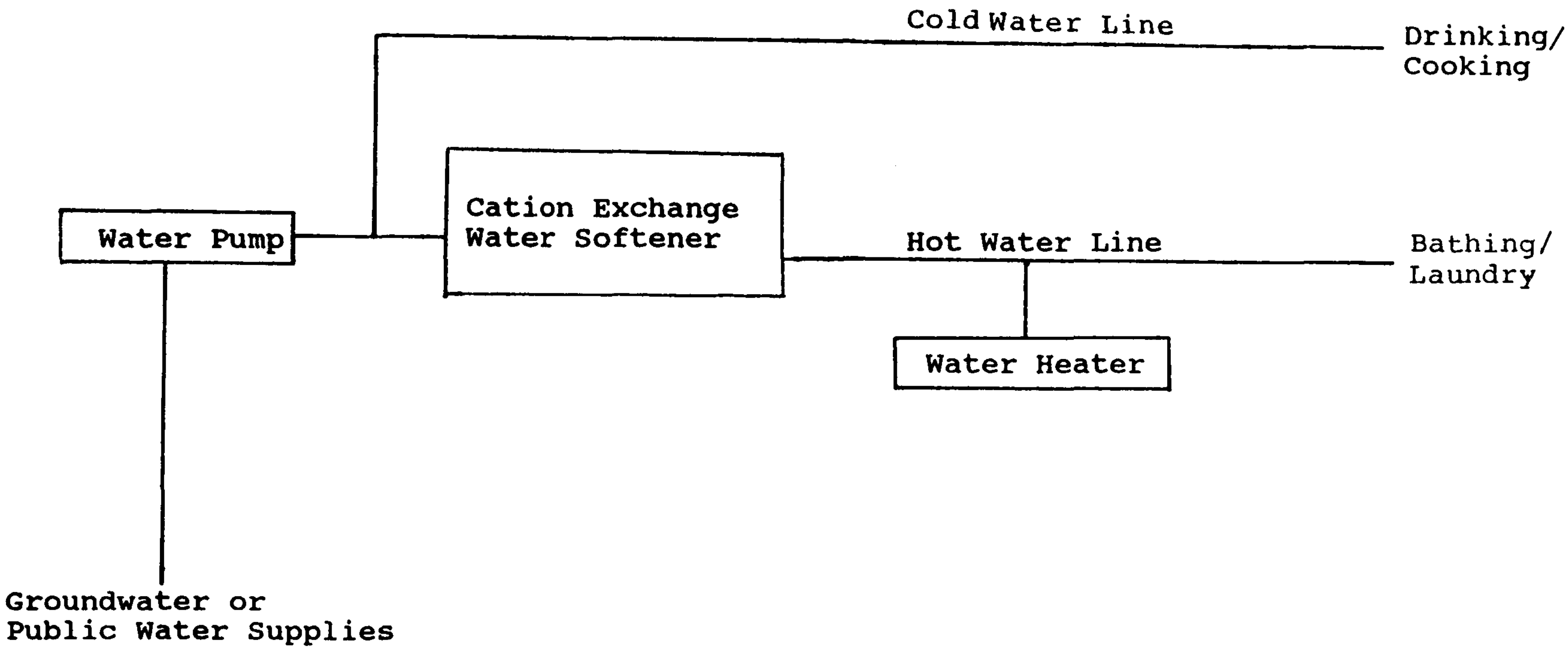


Figure 2. Separate Water Line System

Table 1.

Definition of Terms

<u>Water Hardness</u>

USGS classification of hardness (mg/L as $CaCO_3$):

0-60:	Soft
61-120:	Moderately hard
121-180:	Hard
More than 180:	Very hard

Source: U.S. Geological Survey Water-Supply Paper 2220

<u>Hypertension</u>

A systolic blood pressure greater than or equal to 140 mm Hg., or a diastolic blood pressure greater than or equal to 90 mm Hg., or taking medication for high blood pressure, regardless of level.

Source: National Heart, Lung, and Blood Institute

Chapter 2

WATER SOFTENERS

Hard water is a problem that affects a majority of the people in the United States, because the use of hard water makes it difficult to work up a lather with soap and water. In a survey of municipal water systems of the 173 largest cities in the United States, it was found that water in 70 percent of the cities is hard enough that softening is either required or recommended (Table 2). Although it is difficult to define any regional patterns of water hardness of water supplies, the soft water supplies are located along the Atlantic, Oregon and Washington coast and along the Gulf westward. The hardest water supplies are in the far southwest and in the Great Lakes [10]. Water hardness is expressed in "grains per gallon" (GPG). Water supplies in the United States run from 3 to 50 GPG. Soft water is classified as having 0 to 1 GPG; slightly hard water is 1 to 3.5 GPG; moderately hard water is 3.5 to 7 GPG; hard water is 7-1.05 GPG and over 10.5 GPG is very hard water [11].

A softener is designed to remove calcium and magnesium--the minerals will react with soap to produce soap-curd deposits in the bathtub and sinks, dull-looking laundry, spots on dishes, scaly deposits on faucets and showerheads. Before soap can form a lather, part of the soap molecule reacts with the calcium and magnesium in the

Table 2.

Hardness of Water Supplied by Municipal Water Systems in the United States, 1984

	Raw Water Supplies* Number of Cities
<u>Hardness (mg/L)</u>:	
Less than 61	53
61-120	37
120-180	29
More than 180	45

*A few cities are not included because of insufficient data

Source: American Water Works Association 1984 Water Utility Operating Data.

hard water and form an insoluble curd. The smaller the amounts of magnesium and calcium, the easier the soap can form a lather. The greater the amounts of calcium and magnesium, the more insoluble curds are formed and the more soap is consumed. Formation of scale is the other serious problem. Scale is formed when hard water is heated, and is one cause of water heater failure. As a form of rock, scale build-up gradually coats the interior of pipes and water-heaters, reducing water flow and ultimately they must be replaced.

There are several ways to reduce water hardness: deionization, distillation, reverse osmosis and cation exchange. The method that is best suited for residential use is cation exchange. An ion exchange water softener has four basic components: the resin tank, the resin bed, the brine tank and the control valve. Water softener capacities are given in terms of the number of grains of hardness. The typical household (a family of four persons) softener's capacity is 20,000 grains [11].

The cation exchange softens water by exchanging sodium for the calcium and magnesium. One atom of calcium or magnesium is replaced by two atoms of sodium (Figure 1). In this way, softening can result in increases in concentration of sodium in the softened water. In regenerating, the resin beds being washing with a solution of sodium chloride (common table salt). The harder the water supply, the more sodium that is added to the water to be softened. A softener will consume about five pounds of salt for each regeneration. The increase in sodium levels in the water caused by cation exchange softening is a direct function of the hardness level of the untreated water.

For people who use groundwater, which often is much harder and contains more sodium than surface water, the additional sodium from water softeners may create health hazards on the general population and could adversely affect those who are sensitive to salt or on low sodium diets.

Chapter 3

WATER HARDNESS AND HEALTH

The principal focus of water hardness and health is on possible adverse health effects from ions in drinking water. Water hardness is a geographical variable and it varies according to geographic patterns. Water hardness may be defined as the sum of the polyvalent cations in water. There is no distinctly defined level for a hard or a soft water. Hardness is primarily due to the presence of ions of calcium and magnesium and is expressed as the equivalent of calcium carbonate ($CaCo_3$). Water with less than 75 mg $CaCo_3$/L is considered soft, and above 75 mg/L as hard. Hardness is a complex and variable mixture of cations and anions of water.

Many epidemiological studies show that hardness of drinking water is inversely associated with cardiovascular mortality. The first evidence of an association between human health and water hardness was presented by Kobayashi [12]. After Kobayashi, many studies have been carried out on the possible relationship of water hardness and health [13, 14]. Most of the investigations were done in the United Kingdom, United States, and Canada. They reveal a consistent trend of significant statistical associations between water hardness and the incidence of cardiovascular disease. Most of these reports indicate an inverse association between the incidence of cardiovascular disease and the amount of water hardness. Some reports also indicate a similar inverse association between the water hardness and the risk from other noncardiovascular causes of death as well.

The British Regional Heart Study has examined geographic variations in cardiovascular mortality in Great Britain in respect to drinking water quality. The geographical units were 253 towns in the England, Wales and Scotland region. Pocock et al., found a significant negative association between water hardness and cardiovascular mortality [15]. An association between water hardness and cardiovascular mortality is reaffirmed; towns with soft water tending to have higher death (coronary heart disease and stroke) rates than towns with hard water. The results of British studies indicate that after adjustments for other factors, cardiovascular mortality in areas with soft water was 10-15% higher than in hard waters. However, any further increase in hardness was not associated with lower cardiovascular mortality.

A new study strengthens the link between water softness and risk of cardiovascular disease. Researchers in the Health and Safety Research Division at Oak Ridge National Laboratory compared the well water (an individual nonchlorinated) of 505 Wisconsin farmers, aged 35 to 80, who died from heart attack or stroke (cases), with the well water of 854 living Wisconsin farmers who show no clinical evidence of heart disease (controls) [16]. The study showed the association between water softness and heart disease risk in persons whose water contained low levels of calcium. There is strong evidence in this study of an association between hardness of drinking water and coronary artery disease and cerebrovascular disease. 424 of the 505 cases in this study had evidence of coronary artery disease.

A negative association of water hardness and cardiovascular mortality has been reported in most studies with large geographical areas. Analysis of 484 cities in the United States, Sharrett et al., found that when soft water cities were compared with hard water cities in the same region and the result was adjusted for demographical variables, the mortality rates were found to be approximately 5 percent higher in soft water cities [17].

It has been theorized that soft water may remove a significantly higher proportion of nutrients and elements from foods during cooking than does hard water. The hypothesis that the calcium and magnesium deficiency in areas with soft drinking water increases the risk of ischemic heart disease death rate was supported by the finding that food looses more calcium and magnesium when it is cooked in soft water rather than in hard water [18]. These tests and results may support the hypothesis that an inverse relation between hardness and ischemic heart disease mortality is due to a deficiency of calcium and/or magnesium in soft water. It was found that the sodium content of selected low sodium vegetables can increase as the level of sodium in the cooking water increases (Table 3). The results are of potential significance for persons following low sodium diets with respect to drinking water supplies and cooking practices.

Generally, studies have shown a negative association between cardiovascular disease mortality and water hardness. Lower cardiovascular mortality is found in areas where the hardness of drinking water is high. It has been suggested that preventing the leached trace metals from plumbing materials may result in decreased cardiovascular mortality.

Table 3.

Sodium Contents of Vegetables Cooked Fully-Covered with Water Containing Increasing Sodium Concentration (mg/500 g product)

Vegetable	Uncooked Value	Initial 0	Sodium 100	Concentration (mg/L) 250	Added*
Cabbage	9.6	4.0	61.4**	144.9**	499.1**
Squash	1.3	1.1	26.3**	65.1**	1048.8**
Potato	4.6	4.2	30.8**	73.8**	1040.1**

*ADDED: Concentration of cooking water; 1100 mg Na/L; squash and potato, 4100 mg Na/L.

**: Results are statistically significant from the uncooked and from the zero sodium cooking level, $p<0.01$.

(From Rowan et al., 1981)

Chapter 4

MAGNESIUM

Magnesium Requirements

Magnesium is the second most prevalent cation in living cells and is an essential element of many enzyme systems. The daily magnesium intake recommended by the Food and Nutrition Board of the National Research Council is 60 mg for infants less than 6 months old, 70 mg for 6 to 12-month-old infants, 150 mg for 1 to 3-year-old children, 200 mg for 4 to 6-year-old children, 250 mg for 7 to 10-year-old children, and 300 mg for females 11 years and older. For males the recommended dietary allowances (RDA's) are 350 mg for ages 11 to 14, 400 mg for ages 15 to 18 years, and 350 mg for those 19 years of age and older. The RDA for pregnant and breast feeding women is 450 mg [19]. The average healthy American adult ingests between 240 and 480 mg of magnesium daily [20]. Requirements of magnesium in an average diet for an adult range from 220-300 mg per day [9].

Contribution of Water to Magnesium Nutrition

In a survey of treated water in public supplies of the 100 largest cities in the United States, Durfor et al., reported an average level of magnesium 6.25 mg/L, a maximum of 120 mg/L [10]. A daily intake of 2 liters of drinking water would supply an average of approximately 12 mg of magnesium and a maximum of 240 mg. Where the magnesium level is high, over 50 percent of the RDA could come from 2 liters of water. In this way, drinking water could provide a nutritionally significant amount of magnesium for individuals consuming a diet that is marginally deficient in magnesium. Water contains only a small amount of magnesium and it increases as the hardness increases. A daily intake of 2 liters of hard water (10 gr/gl) provides 40 to 50 mg of magnesium per day.

Health Effects

Magnesium is an essential element in human and animal nutrition. It is the most abundant intracellular divalent cation in both humans and animals. It is an essential element of many mammalian enzyme systems. Magnesium deficiency in humans is most often observed in patients with gastrointestinal diseases that lead to malabsorption and in those with hyperparathyroidism, bone cancer, aldosteronism, diabetes mellitus, and thyrotoxicosis [21]. In patients with renal disease a large amount of magnesium intake can lead to sever toxicity resulting in muscle weakness, hypertension, sedation, confusion, decreased deep tendon reflexes, respiratory paralysis, coma, and death.

Hypomagnesemia occurs in alcoholics, persons performing hard labor in hot climates, patients with heart failure and those receiving diuretics. These deficiencies can be overcome by oral administration of magnesium compounds.

Epidemiologic Studies

Magnesium has been known to have a blood pressure-lowering effect, particularly in the treatment of eclampsia and pre-eclampsia. There is almost no evidence of a hypotensive effect of increased dietary magnesium in essential hypertension.

In a study of Korean population or in the NHANES I data, no relation between magnesium excretion and blood pressure were seen [22, 23]. There is no evidence to define the etiologic role of magnesium deficiency in human hypertension or to support the use of magnesium supplementation as antihypertensive therapy in essential hypertension. There is no direct evidence on the relation between magnesium intake and the prevalence of hypertension in humans.

Chapter 5

CALCIUM

Calcium Requirements

For Americans, the Food and Nutrition Board of the National Research Council has recommended daily calcium intakes of 360 mg for infants less than 6 months old, 540 mg for 6 to 12-month-old infants, 800 mg for children aged 1 to 10 years, 1,200 mg for 11 to 18-year-old children, and 800 mg for an adult. The RDA for pregnancy and breast feeding women are increased to 1,200 mg/day [19].

Contribution of Water to Calcium Nutrition

In a survey of treated water in public supplies of the 100 largest cities in the United States, Durfor et al., reported an average calcium level of 26 mg/L and a maximum of 145 mg/L [10]. A daily intake of 2 liters of drinking water would supply an average of 52 mg/day and a maximum of 290 mg/day. It would represent 5 to 10 percent of the usual daily intake, or approximately 6.5 percent of the adult RDA. Hard water (10 gr/gl) provides approximately 112 mg per day. The usual daily intake of hard water would contribute approximately 36 percent of the adult RDA. In general, public drinking water contributes a small amount to total calcium intake, but in some instances, it can be a major contributor.

Health Effects

There is no clearly defined calcium deficiency in humans. A prolonged dietary deficiency of calcium has been linked to osteoporosis, which affects a large portion of older people and is most prevalent in older women [24]. Additionally, increased calcium intake has been shown to lower blood pressure in people [25, 26]. Kidney stones in people have been observed with high calcium intake [27]. Calcium is relatively nontoxic when administered orally.

Epidemiologic Studies

Epidemiologic studies suggested a link between lower calcium intake and a higher incidence of hypertension. Many recent studies have focused on the relationship between inadequate calcium intake and increased incidence of hypertension. Investigators have questioned the hypothesis that lower intake of dietary calcium may be the cause of the epidemic of hypertension [28]. Analysis of the data from the 1971 to 1974 National Health and Nutrition Examination Survey (NHANES I) by McCarron et al. divulged an inverse relation between dietary intake of calcium and blood pressure [29]. Additionally, an inverse relation between dietary calcium intake and blood pressure has been provided by other population studies [30, 31].

Recently an analysis was conducted by the NHANES official investigators. Their analysis was based on the same data, combined with the more recent NHANES II. They concluded that there was no association between calcium intake and blood pressure [29]. The result of this investigation did not support the hypothesis that lower dietary calcium intake may be the cause of the epidemic of hypertension, although the results did not rule out the possibility that such an association could exist. On the other hand, MacCarron and Morris, in a double-blind study, reported no change in blood pressure of 32 normotensive subjects after 8 weeks of calcium supplementation, but in 48 hypotensive subjects, mean supine blood pressure decreased by 3.8/2.3 mmHg. Their results showed a significantly lowered systolic and diastolic blood pressure in the hypertensive subject [32]. In this manner, calcium supplementation may affect only a subgroup of the hypotensive population. It may be possible that calcium supplementation is a weak antihypertensive agent only a subgroup of the hypertensive population. The possible benefit of calcium supplementation must be weighed against the risk of risk of a higher incidence of kidney stones. Certain studies have suggested that elevated total serum calcium levels contribute to high blood pressure [33, 34]. Other reports conclude that a deficiency in serum calcium levels has the same effects [35].

Chapter 6

SODIUM

Sodium Requirements

Salt is a combination of two minerals - sodium and chloride. Approximately 40% of salt is sodium. One teaspoon of salt, which weights 5 grams, contains about 2 grams of sodium. The average adult American consumes about 2 to 4 teaspoons of salt a day, which is equivalent to 4 to 8 grams of sodium. The estimated adequate and safe intakes for sodium range from 1,100 to 3,300 mg/day for healthy adults, the equivalent of approximately 1/2 to 1 1/2 teaspoons of salt. For infants, the estimated adequate and safe intakes are approximately 115 to 750 mg/day [18]. Individual requirements are varied with climate, occupation, physical activity and other factors.

Contribution of Water to Sodium Nutrition

A daily intake of 2 liters of drinking water with an average sodium level of 28 mg/liter, the contribution of sodium in water to the estimated adequate and safe intake would be approximately 1.7% to 5.0%. Adult fluid intake averages 1.5 to 3 liters/day. In this manner, sodium intake from drinking water represents less than 10 percent of the total intake of 3,000 to 4,000 mg as long as the sodium content of the water does not exceed 200 mg/liter.

Health Effects

Sodium toxicity leading to hypertension has been associated with intake of salt greater than 30 g/day, but may occur at lower intake in salt-sensitive individuals suffering from hypertension, congestive heart failure, liver cirrhosis, or renal disease. The prevalence of hypertension in the adult American population is 15 to 20 percent among Caucasians [36] and substantially higher among blacks [37] (Table 4). It has been estimated that 30 to 40 million Americans are afflicted with this disease.

Sodium deficiency in humans is often observed in patients with renal disease, diuretic therapy, osmotic diuresis, adrenal insufficiency, vomiting, diarrhea, wound drainage, excessive sweating, burns, mucoviscidosis, peritoneal drainage, and pleural, pancreatic, and biliary fistulae drainage. Hyponatremia occurred by poor secretion of antidiuretic hormones, alcoholic cirrhosis, adrenocortical insufficiency, congestive heart failure, and cachexia [38]. Patients with kidney failure, show a direct relationship between sodium intake and blood pressure [39]. Sodium restriction alone can control one segment of the hypertensive population, thereby reducing the need for diuretics [40]. Elliot et al. reported adverse health effects in people on low sodium diets when they consumed water with a high sodium level [41].

Table 4.

Prevalence of Hypertension by Race

All Ages			
All Races	White	Black	Other
Number per 1,000 persons per year			
122.1	120.0	145.7	87.4

Source: Health of Black and White Americans, 1985-87. National Center for Health Statistics, Series 10, No. 171 (Jan. 1990).

Groups	Unweighted Sample Size	Prevalence (Percent)
Black	1436	33.8
Asian and Pacific Islanders	1757	20.0

Source: Gordon R. Stavig et al.: Hypertension and Related Health issues Among Asians and Pacific Islanders in California. Public Health Reports, Volume 103, No. 1 (Jan.-Feb. 1988).

Epidemiologic Studies

Epidemiological evidence supports the notion that by reducing dietary sodium intake, blood pressure may be lowered, or the development of hypertension may be avoided. Hypertension is actually nonexistent in many unacculturated societies, and blood pressure does not increase with age [42]. Page et al. examined numerous societies of different ethnic backgrounds in various parts of the world and they concluded that hypertension was not attributable to malnutrition, thinness or different amounts of stress [43]. They explained the lack of hypertension by the extremely low dietary salt intake by these people. Maddocks compared different populations in New Guinea and found that in the highlands no hypertension was found and blood pressure did not increase with age. In coastal communities, in which people consumed salted canned foods, blood pressure increased with age and hypertension was present [44]. Studies in other primitive societies confirmed an association between blood pressure and sodium intake [45, 46]. Subjects from primitive societies with low blood pressure have a low sodium intake; however, they also ingest large amounts of potassium and are leaner in stature and more physically active than industrialized societies subjects.

Several epidemiological studies have been criticized because their blood pressure measurements were not standardized and sodium intake was estimated based on dietary recall or on urine collections, without matching age, sex and weight [47]. As opposed to cross-cultural studies, studies of the correlation between dietary sodium intake and blood pressure within industrialized societies have been almost uniformly negative. Dahl et al. conducted a correlation study based upon dietary recalls regarding dietary sodium intake [48]. They reported similar mean blood pressure in study groups whose intake of salt was characterized as low, average, or high. Hypertension, however, was more common in those with high dietary salt intake. Analysis based on the National Health and Nutrition Examination Survey (NHANES I) data found no direct correlations between salt intake and blood pressure. The reason why no relationship was found between sodium intake and hypertension in industrialized societies may be the relatively wide range of dietary salt intake in those populations. It is also likely that sodium intake in industrialized societies is high enough to raise blood pressure only in genetically more susceptible salt-sensitive individuals, who represent a significant minority of the people. In societies which consume a large amount of salt, a significant minority of the people develop hypertension. With this reason, no correlation between blood pressure and sodium intake in the whole population would be expected. Since dietary salt intake is culturally determined, it could be expected that within a given population, salt intakes should be similar regardless of blood pressure.

Salt loading studies in humans have been short-term. The effect of varied sodium chloride intake from 10 to 1500 mmol per day in normotensive volunteers was studied by Luft and he found an increase in blood pressure in some subjects but not in others. Black subjects were more sensitive to salt than white subjects. American blacks are more susceptible to hypertension than American whites who consume comparable amounts of sodium chloride [49]. In blacks, the disease is often more severe and is more likely to be fatal at a younger age than in whites. It is estimated that some 35 to 40 percent of all American blacks have or will have high blood pressure.

From the available epidemiological evidence, the pathogenesis of essential hypertension is not specific to sodium retention. Sodium intake cannot be adduced as a unifying hypothesis to account for the disease [50]. However, a subset of salt-sensitive individuals has been identified in several epidemiologic studies [51]. More than 50 studies have investigated the effect of salt intake on blood pressure. These studies showed that decreases in blood pressure with salt restriction were related to the initial blood pressure levels.

Recently, the National Institute of Health appointed an advisory committee to review the epidemologic evidence regarding nonpharmacological interventions [52]. This advisory committee could only recommend weight control, alcohol restriction and sodium restriction as supplements to therapy with antihypertensive drugs.

Salt-sensitive

Individuals with high blood pressure, affecting some 50 million individuals in America, are a diverse group. Some are obese, some have a genetic background of heart disease, and some eat foods high in saturated fats. In industrialized societies, salt intake is high enough to raise blood pressure. One part of the hypertensive population is sensitive to sodium, which is one component of salt. These individuals are known as salt-sensitive because they are genetically more susceptible to the potential blood-pressure elevating influence of sodium than salt-resistant individuals, whose hypertension seems to be unrelated to the amount of salt they ingest. This may be the reason why no association between increased blood pressure and sodium intake in the whole population is expected. Approximately half of American adults who develop hypertension, a persistent elevation of blood pressure above normal levels, are affected by dietary sodium intake. There is probably a subset of salt-sensitive individuals in whom salt intake is an important determinant in the development of hypertension.

The idea that only a minority within a population are genetically more sensitive to sodium than others has been clearly pointed out in the laboratory [51]. However, a recent study suggests that other hypertensives - known as salt-resistant - would not benefit from a diet low in salt [53, 54]. After the onset of established hypertension, secondary vascular and renal abnormalities are likely to develop, which increase the proportion of salt-sensitive subjects [49]. By knowing which group they are in, hypertensive individuals can help to promote their own good health.

Chapter 7

CONCLUSIONS

In the United States, current levels of magnesium in drinking water supplies seem to present no threat to human health. The WHO, however, has recommended a maximum of 150 mg/L [55]. A daily intake of 2 liters of hard water (10 gr/gl) provides 40 to 50 mg of magnesium per day. For people who have heart disease and those using diuretics, this contribution from drinking water is important and may provide nutritional benefit.

In the United States, current levels of calcium in drinking water supplies do not offer risks to human health. In patients with dietary calcium deficiencies, the presence of this element in drinking water may provide nutritional benefit. Removal of calcium from water, therefore, may have adverse health effects on a general population. Until epidemiologic studies can give a clearer answer regarding calcium level, the best recommendation for the general population is daily intake of 2 liters of calcium-rich water to meet the recommended daily allowances (RDA's) for that nutrient.

The Environmental Protection Agency (EPA) suggests optimal sodium levels of less than 20 mg/liter for drinking water and advises suppliers of public water with sodium concentrations above 20 mg/liter to prevent further increases in sodium levels during the treatment process [56]. However, the EPA does not require removal of sodium if the levels are higher than 20 mg/liter.

High level intake of some nutrients will negatively affect the absorption of other nutrients. For a general population, a moderate reduction in the sodium intake would not be harmful. In the future, it may be prudent to advise determination of salt-sensitivity. It is unknown now what percentage of the hypertensive population is sensitive to sodium.

Water softening by cation exchange at individual homes increases the sodium level of drinking water, and the increased sodium level could adversely affect those who are sensitive to salt or on low sodium diets; thus avoiding such an increase might be prudent.

To prevent potential health hazards for the general population, no consumption of softened water by cation exchange water softener should be recommended. Alternatively, it is possible to place a warning sign on cation exchange water softeners about the increased sodium level caused by the water softener.

If a soft water is needed for some practical reasons, a "Separate Water Line System" should be recommended for home owners. The line from groundwater which supplies the drinking and cooking water bypasses the softener (unsoftened water in the cold water line). Other lines for bathing and laundering are connected to the softener (softened water in the hot water line only). Additional research is needed to provide a method for removal of sodium from softened water.

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