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SODIUM (Na) LEVELS IN DRINKING WATER (H_2O) AND DEVELOPMENT OF HYPERTENSION IN CHILDREN

by

SARA REYNOLDS SCHIFFMAN

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Nursing
in the College of Nursing
and in the Burnett Honors College
at the University of Central Florida
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ABSTRACT

This integrative review of the literature focused on sodium (Na) content in drinking water (H_2O) supplies and the subsequent effect on blood pressure levels in children. Studies for this review were drawn from the Cumulative Index of Nursing and Allied Health, PubMED, Science and Technology Databases, PsychInfo, United States (US) Environmental Protection Agency (EPA) and EPA in Florida websites.

Criterion for inclusion in the data base searches were hypertension, high blood pressure, sodium in drinking water, drinking water salinity, children or preg*. Subsequently, further article selection criteria included children (under 18 years of age) and published in the English language (*N*=59). Findings of the review as summarized in this thesis could guide nursing research, education, policy and practice related to primary, secondary and tertiary interventions associated with sodium levels in drinking as a contributing factor to blood pressure levels in children.

DEDICATION

I would like to dedicate this thesis to my family and friends who were instrumental in the concepts and completion of this thesis.

I thank my husband Stephen for his unwavering support in picking up all the loose ends of our lives while I hunkered down to complete this thesis and this phase of nursing school. I love and appreciate you.

I thank my son Brad for challenging me intellectually to keep up with him.

I thank my brother John, his wife Rebecca, and their children Ashley and Jake, for making sure I got out of my office once in a while for a good meal and some laughs.

Last but not least, I thank my friends from nursing school who helped me through the days where all we could imagine was panic, horror and dread. Together we have challenged each other intellectually and developed new skills to become competent nurses. As we venture into our new careers, know that you have each had a profound effect on my education and confidence, and I look forward to having you as my colleagues.

ACKNOWLEDGEMENTS

It is with tremendous gratitude that I thank Dr. Angeline Bushy for her professionalism and grace while I pursued this topic which is dear to my heart. Her exceptional skill in helping me to clarify my topic, while guiding the development of this review through gentle critique and superb organization, has left me in her debt.

I would like to thank my committee members, Dr. Maureen Covelli and Dr. H. Edward Fouty. Thank you for your support and ideas that have helped to balance the information herein.

I would also like to thank the Burnett Honors College for creating this opportunity in which I have been able to refine my research skills and produce this thesis. Denise Crisafi, you have made navigating this process particularly painless. You always have a solution and a smile, I thank you for that.

Thank you to all of the teaching staff on the Daytona Beach campus of UCF who encouraged and supported the amazing education I received while pursuing my new career in nursing. You have successfully created a learning environment in which my mind has been opened and stretched to new concepts and understanding that inspire me, and facilitate my continuing education.

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CHAPTER 1: INTRODUCTION

The purpose of this thesis is to complete an integrative review of research on Sodium (Na) content in drinking water (H_2O) supplies and the subsequent effect on blood pressure levels in children under the age of 18 years. Findings of this thesis may guide research, education, clinical practice, and policy regarding sodium levels in drinking water which is a contributing factor to blood pressure levels in children.

This integrative review analyzes and synthesizes the literature related to sodium levels in drinking water and hypertension in children. The studies for this project were drawn from the databases of Cumulative Index of Nursing and Allied Health, PubMED, Science and Technology Databases, PsychInfo, and government websites. The criterion for inclusion consisted of research articles on sodium levels in drinking water and hypertension in children up to 18 years of age written in the English language. Search terms included hypertension or high blood pressure, sodium in drinking water or drinking water salinity, and children or preg*. The search resulted in 59 articles (Appendix A). Of these, 11 were clearly not related to saline levels in drinking water, six were duplicates and clearly irrelevant, and 30 articles were non-human in context. The remaining 12 studies were included in the literature review. Six other studies were identified through reference lists while reviewing the articles included, for a total of 18 articles. Of these, two were retrospective follow-up studies, one was a descriptive study, and 15 were empirical studies.

The next chapter (Two) presents a review of the 18 articles included in the analysis. Chapter three examines the implications for nursing and identifies weakness in this integrative review.

CHAPTER 2: LITERATURE REVIEW

Background

The World Health Organization (WHO) (2005) published several papers on the subject of water quality, the effects of nutrient levels in water supplies, and the relationship with human health. WHO (2005) experts contend that while sodium is a necessary dietary component to maintain electrolyte and fluid balance, in excess it has been shown to have deleterious health effects. In particular, a small segment of the population is hypertensinogenic, or salt sensitive. For these individuals even slight increases in sodium such as that found in water supplies may have adverse health effects such as hypertension and its associated sequelae.

Sodium Intake

Sodium is found in virtually all food and water. Current dietary guidelines established by the Centers for Disease Control (CDC) (2013) recommends that adults consume less than 2300 mg of sodium per day in conjunction with foods that are potassium rich such as fruits and vegetables. However, approximately half of the American population should be consuming less than 1,500 mg per day; specifically those over the age of 50, are of African American origin, have a history of high blood pressure, kidney disease, or diabetes. For children, U.S. Department of Health and Human Services (USDHHS) (2005) recommends an adequate daily sodium intake of only 1200 mg per day for 4- to 8-year-old children and 1500 mg per day for older children. It is currently estimated that most Americans exceed recommended dietary sodium every day.

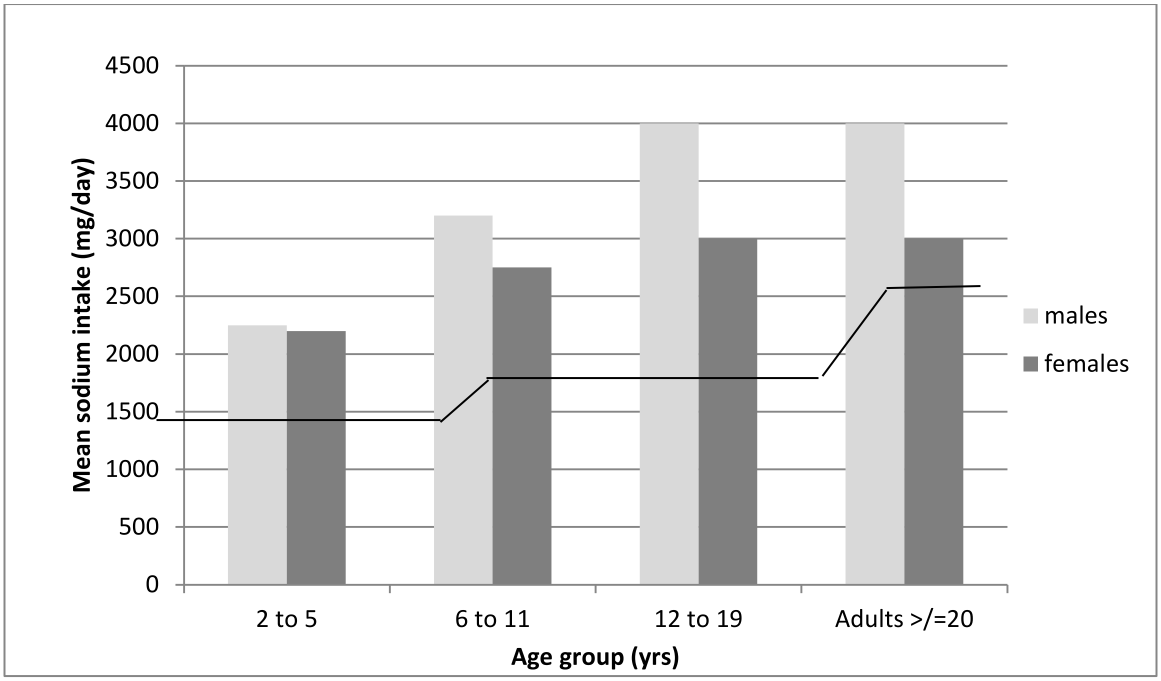

Figure 1 Mean sodium intake (excluding table salt) by age and sex, and recommended levels* (National Health and Nutrition Examination Survey United States 2007-2008)

Genomics

Throughout most of history the survival of humans has largely depended upon the ability to conserve and retain sodium. Humans are genetically programmed for salt intake of 2500 mg/day, and excess intake can present a major challenge to the physiologic systems working to excrete excess through the kidneys (He & MacGregor, 2010).

African Americans in particular have a protective response which allowed for better survival in warm climates while performing hard labor. It is theorized that over the centuries genetic evolution allowed for the retention of sodium as a protective mechanism. This change translated to an increased sensitivity to sodium in many modern day African American individuals. This genetic alteration puts them at risk for hypertension with its sequelae including coronary artery disease and stroke. Consequently, a dietary modification to reduce sodium often shows decreased hypertension among African Americans (DeCrane, 2004).

Also, at this end of the spectrum, the Yanomamo Indians of Brazil have demonstrated the ability to endure extremes of sodium intake of less than 0.2 grams of sodium per day. Their ability to survive extremely low levels of sodium intake is a reflection of the capacity of the human body to conserve sodium by markedly reducing losses of sodium through urine and perspiration. It has been estimated that the body requires a minimum of 0.18 grams of sodium per day to function. Although it must be noted that it is unlikely that a diet providing this level of sodium is sufficient to meet the dietary requirements for other nutrients. At the other end of the spectrum, Northern Japanese populations have adapted to survive with an excessive sodium intake of 10.3 grams of sodium per day (Panel on Dietary Reference Intakes, 2005).

Mutations in several genes that cause Mendelian forms of hypertension or hypotension have been identified in molecular genetic studies. These genes affect the kidneys ability to excrete sodium and there is a dramatic effect on blood pressure in these individuals which correlates to dietary salt intake. Genetic disorders such as these are considered rare yet are clearly indicative of the importance of salt intake in regulating blood pressure (He & MacGregor, 2010). Several genetic mutations have been identified in individuals with hypertension, although the role of those mutations in the pathophysiology of hypertension remains to be determined. In respect to children, hypertension may have a genetic basis. As our understanding of human genomics improves, the current label affixed to many hypertensive children may eventually be shown to be a reflection of genetic mutation (Flynn, 2003).

Physiological Response to Sodium

A comprehensive discussion of the physiology of sodium uptake and hypertension is beyond the scope of this paper. Essentially, sodium is a necessary component for the body to function. It is required for maintaining fluid balance in the body, transmitting nerve impulses, and influencing the relaxation and contraction of muscles. Excess sodium intake can lead to fluid retention, increased blood pressure, stroke, left ventricular hypertrophy, stomach cancer, kidney disease, renal stones and osteoporosis, and asthma (He & MacGregor, 2010). The equilibrium of serum sodium is achieved through various body systems and hormones that influence the sodium and chloride balance through the renin-angiotensin-aldosterone axis, the sympathetic nervous system, atrial natriuretic peptide, the kallikrein-kinin system, and various intrarenal mechanisms. These and other factors regulate the renal medullary blood flow and thereby sodium excretion (Panel on Dietary Reference Intakes, 2005).

Essentially, water retention associated with sodium expands extra cellular volume. This excess volume triggers compensatory mechanisms intended to increase urinary sodium excretion. As long as the excess sodium is consumed, approximately 1.5 L of extracellular fluid is retained. Extracellular fluid exacerbates all forms of sodium and water retentions, including heart failure and is a major cause of edema in women, aggravating both cyclical and idiopathic edema. Increased risk of stroke, independent of increase in blood pressure, has been demonstrated in significant correlations between 24 hour urinary sodium excretion and stroke mortality (He & MacGregor, 2010).

The WHO (2005) estimates that 15% of the population is salt sensitive. Determination of salt sensitivity is technically very difficult to perform. Consequently, studies addressing salt sensitivity have not been conducted at the population level (DeCrane, 2004). Conversely, according to the Panel on Dietary Reference Intakes (2005), concerns that a low level of sodium intake may adversely affect blood lipids, insulin resistance, and risk for cardiovascular disease have been raised but a preponderance of evidence based on Adequate Intake (AI) guidelines does not support this school of thought at this time. Clinical relevance of modest increases in plasma renin activity as a potential indicator of adverse effects of inadequate sodium is uncertain. However, the benefits of decreased blood pressure are well accepted benefits of dietary sodium reduction.

Hypertension in Children

Hypertension is a mounting health problem in children and adolescents. Despite the relatively high prevalence of hypertension in these age groups, the condition continues to go under diagnosed (Riley & Bluhm, 2012). Falkner (2010) followed the epidemiology and natural history of hypertension in children and adolescents, leading to the remark that although cardiovascular disability and death do not occur in hypertensive children there are immediate markers of target organ damage. Damage may include left ventricular hypertrophy, thickening of the carotid vessel wall, retinal vascular changes, and even subtle cognitive changes that are detectible in children and adolescents with high blood pressure. Childhood hypertension generally leads to hypertension in adulthood. Hypertension in adulthood is the leading cause of premature death around the world (Riley & Bluhm, 2012).

Due to the complexity of obtaining an accurate blood pressure reading in children, many children who are hypertensive may have a blood pressure reading which appears normal. Therefore, along with child's age, history, physical exam findings and degree of blood pressure evaluation, laboratory studies should also include evaluation of renal parenchymal disease, coarctation of the aorta, renovascular, reflux nephropathy, endocrine disorder, and tumors. If the necessary studies are not available through local offices or hospitals, the child should be sent to a more specialized pediatric center for evaluation.

Evaluation for the presence of hypertensive target organ damage should be included in order to make the diagnostic evaluation of the hypertensive child more comprehensive. Findings of left ventricular hypertrophy, hypertensive retinopathy, micro albuminuria, and increased thickness of the carotid arteries have all been identified in children with primary hypertension. Diagnostics may require the use of echocardiography or ambulatory blood pressure monitoring to determine the severity of the child's hypertension which is essential for planning treatment and follow-up (Flynn, 2003). Early detection of children who may be at risk for hypertension allows for the initiation of long term protective behaviors and habits which will extend into adulthood (Vessey et al., 2001). Identification, examination, and treatment of children with high risk blood pressure are essential to reducing the clinical and public health burden of cardiovascular disease in adults (Falkner, 2010).

Limited research has been conducted regarding sodium requirements for normal growth and development of infants. In young children, growth failure has been noted with sodium wasting disorders such as isolated hypoaldosteronism which leads to a reasonable conclusion of the need for adequate sodium in early life for the normal growth and development (Panel on Dietary Reference Intakes, 2005). Concerns of higher blood pressure as a result of infants fed formulas with higher sodium content due to concentrations in available drinking water have been raised. An association has been found between formula feeding and elevated blood pressure later in life and has been attributed in part to the differences in sodium content of instant formula and human milk (World Health Organization, 2005).

Pomeranz, Dolfin, Korzets, Eliakim, and Wolach (2002) noted that a study conducted using Dahl salt sensitive rats that were exposed to a high sodium diet indicated particularly detrimental effects when the exposure began very early in life at the time of weaning. The brief exposure to the high sodium diet early in life led to permanent hypertension even though they were later maintained on a low sodium diet. While this was an animal study necessitating caution in generalizing findings to humans, it does bear consideration.

Sodium Levels in Drinking Water

Water contains naturally occurring small amounts of gases, minerals and organic matter. Neither ground water nor surface water has ever been chemically pure. Total concentrations of various substances which are found dissolved in drinking water can be in the hundreds of mg/L and still be considered good quality (World Health Organization, 2005). Sodium level in drinking water may be due to a multitude of factors. Existing underground mineral deposits, excessive evaporation of surface water leading to concentrated water supply, side effects of water treatment processes (e.g. water softener systems), or the unintentional runoff from treating icy road conditions all can affect sodium levels in drinking water supplies. Of special concern to geographical coastal regions is the intrusion of ocean water into fresh water aquifers.

Varying degrees of salt water intrusion have been documented in the coastal areas of the United States. In most areas the contamination has been limited to small parts of an aquifer and specific wells, having little or no effect overall on the local groundwater supply. In other instances, there is evidence of substantial saltwater contamination in regions such as Cape May County, New Jersey; Monterey, Ventura, Orange and Los Angeles Counties, California; and southeastern Florida (Barlow, 2010).

The combination of storm surges and overuse of water supplies is drawing seawater into existing freshwater aquifers causing salination and contamination of the drinking water supplies of these coastal regions. This natural phenomenon of saline intrusion contributes to increased levels of sodium in drinking water, which in turn, could contribute to hypertension in children and adults.

Florida State Safe Water Policies

According to Florida's Department of Environmental Protection (DEP) (2012), a source of high quality ground water lies beneath all of Florida. This resource is accessed by 90% of the Florida population of 14 million residents, plus the 42 million annual visitors, who rely on it for their drinking water. This fragile coastal water system has slowly become overextended and is vulnerable to overuse and contamination.

In 2002, the United States government established a drinking-water advisory for high levels of sodium in which the United States Environmental Protection Agency (USEPA) recommended a health-based guidance level of 20 mg/L in drinking water (Barlow, 2005). The DEP has set the standard for Florida's drinking water at 160 mg/L (Florida Department of Health, 2005). The DEP further noted that in the case of private drinking water wells, or potable wells, there is no required sampling to determine levels of sodium (Florida Department of Health, 2005). No guidelines have been released by the WHO regarding safe salinity levels in drinking water other than the acknowledgement that sodium levels greater than 200 mg/L are unacceptable to taste (Khan et al., 2011).

The Florida Department of Health (2012) in conjunction with the Centers for Disease Control (CDC) recognized that as many as 20% of Florida residents receive their drinking water from limited use public water systems and private wells. Residents with private wells are responsible for ensuring that their own water is safe to drink. The Department of Health strongly recommends that the private well owner have their well tested for bacteria and nitrates and other contaminants, including sodium, at least once per year by the local health department or a state certified lab (Florida Department of Health, 2012).

Barlow and Reichard (2010) noted that although overuse and contamination of groundwater are not uncommon, the unique issue to Florida is the proximity of the fresh water aquifers to salt water in extensive coastal regions. This proximity leads to irreversible salt water intrusion with the overuse of these fresh water aquifers and contamination of drinking water supplies. While fresh water supply is a limited resource all over the world, this source is dwindling in Florida. Contamination of the water supply may lead to unintentional increased exposure to dietary sodium particularly in rural areas with the use of private water wells.

Environmental Factors Contributing to Increased Sodium Intake

Salt has been used for thousands of years as a food preservative. In the current culture of fast food and processed foods, sodium is used for flavor as well as for its preservative qualities. Preparation of food may include the addition of table salt while cooking, and the Mayo Clinic (2011) reminded us that one teaspoon of table salt alone has 2,325 mg of sodium. This combination of factors culminates in the unintended ingestion of excessive sodium for most Americans. Water is ingested as plain drinking water, mixed in beverages, and in food. Using water with high sodium content as drinking water or in the preparation of food can also unintentionally add sodium. For example, cooking fresh or frozen vegetables in this type of water will lead to absorption of the sodium during the cooking process (Tuthill & Calabrese, 1981).

In a South Carolina survey designed to determine the amount of sodium the average citizen consumes from drinking water, Lackland, Weinrich, Wheeler, and Shepard (1985), estimated that as much as 64% of the total sodium intake of individuals was consumed through drinking water. In Massachusetts a study using bottled water to replace local drinking water to assess the effect on blood pressure of school children. By lowering the sodium level ingested via bottled drinking water, the study observed a correlation of lowered blood pressures with lower sodium in drinking water (Calabrese & Tuthill, 1985).

Exclusive breast feeding is promoted by the WHO's Global Strategy on Infant and Young Child Feeding. This is not always a feasible strategy and it may be necessary to use a feeding formula. When reconstituting instant formula, variable mineral content found in drinking water sources will result in variability in the mineral content of the formula milk. Some types of water may not be suitable for this use, due to either a deficiency of appropriate minerals or to the presence of excess salts that may be harmful to infants and young children. Sodium can be a particularly harmful additive as the requirement of infants for sodium is low (World Health Organization, 2005).

Physiological Adaptations to Sodium Intake

The definition of a *drug* is any substance that affects living systems (Tekol, 2008). Therefore, by definition sodium can also be considered a drug as it has effects on living systems. Drugs may exert several undesired effects which may be classified as pharmacological, pathological, and genotoxic undesired effects. Undesired effects of pharmacological drugs are reversible as effects end with the discontinuation of the drug use. Pathological effects that are undesired are generally irreversible, although some effects may be improved as affected cells regenerate, or by adaptive mechanisms. Neoplastic cells may develop as undesired genotoxic effects. Drugs may also have teratogenic effects, as shown in developmental disorders in the fetus (Tekol, 2008).

Available evidence indicates that sodium exposure in utero establishes the beginning of essential hypertension and continues to develop insidiously parallel to sodium intake during the individual's life (Tekol, 2008). Hypertension in pregnancy is associated with both acute and long term adverse outcomes including impaired liver function, low platelet count, intrauterine growth retardation, preterm birth, and maternal and perinatal deaths (Khan et al., 2011).

Regarding salinity in drinking water and maternal health, a coastal area of Bangladesh was recently found to have excessive salt water intrusion of the local drinking water supplies. The encroachment is seasonal in nature as it is tied to the rainfall patterns and the upstream withdrawal of freshwater drinking supplies that rely heavily on rivers, and tube wells or groundwater, affecting the drinking water of approximately 20 million people who are living along this coastal area in varying degrees (Khan et al., 2011).

Khan et al. (2011) studied these effects of water salinity on maternal health (N = 107) in these coastal villages in Bangladesh with a total population of 157,500 people. Using indirect estimates provided by the Centre for Environment and Geographic Information System (CEGIS) in Bangledesh for data from 1998-2000, researchers were able to estimate average levels of salt consumption from river water and shallow groundwater drinking sources for the people residing in these villages. For the purpose of their study a conservative water intake of 2 L/day per person was estimated.

A random sample of pregnant women (N = 343) between the ages of 13 and 45 years of age in Bangladesh, had their blood pressure monitored the 20th week of gestation. The study occurred between October 2009 and March 2010, which is the dry season in that region. The sample provided information on their drinking water sources. Also, a urine sample was measured, for sodium concentration by an independent laboratory. The daily sodium excretion had a mean of 3.4 g/day (Khan et al., 2011). This is well above the recommended levels of <10 mEq/L, or < 23 mg/L (Huether & McCance, 2012). Khan et al. (2011) reminded us that urinary excretion of sodium is a reasonable estimate of salt intake in physiological conditions as 98% of sodium absorption comes from food, and urinary excretion is 86% of intake.

Khan et al. (2011) also studied medical records of 969 pregnant women in the same population who were referred to the only local hospital for antenatal care or pregnancy related complications due to hypertension between July of 2008 and March of 2010. They identified 90 cases of hypertension in these women, of whom 70 developed hypertension during the dry season versus 20 who developed hypertension during monsoon season. This indicates a distinct seasonal pattern relating to the sodium content in available drinking water supplies.

In regard to children's health, Pomeranz, Dolfin, Korzets, Eliakim, and Wolach (2002), found that increased sodium concentrations in drinking water also led to an increased blood pressure in neonates when evaluating three groups of children (N = 73), in Israel during the first two months of life. The first group of infants (n = 25) received powdered formula diluted with low sodium mineral water (LSMW) having a sodium concentration of 32 mg/L of water. The second group of infants (n = 33) received powdered formula which was diluted with high sodium tap water (HSTW) having a sodium concentration of 196 mg/L of water. The third group of infants (n =

15) were breast fed and used as the control group as human breast milk is considered to be a low sodium food.

The three groups of neonates were compared through weekly measurements of weight, height, head circumference, heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP), all measured while the children were asleep for the first eight weeks of life. Urinary sodium: creatine ratios were measure each month during the two month study. All three groups had equal gains in weight and height. Therefore caloric intakes, and thereby the fluid intakes, were considered equal for all of the neonates. It was determined that the only significant difference was the sodium content of the food (Pomeranz et al., 2002).

Pomeranz et al. (2002) further demonstrated no difference in heart rates in the study groups during the beginning of the study period, but by the sixth week there was a significant increase in the SBP, DBP, MAP, and the urinary sodium: creatine ratio in the neonates who received the high salt diet. Manufacturers of powdered milk formula have stated that sodium values of formula approximate those found in breast milk, while ultimately the sodium concentration of prepared formula is dependent on the concentration in the diluting water used in its preparation. Pomeranz, Korzets, Vanunu, Krystal, and Wolach (2000) also found a correlation of increased sodium concentrations in drinking water to increased MAP and SBP in an empirical study of 956 fourth and fifth grade Israeli schoolchildren.

A randomized trial of sodium intake and blood pressure in newborn infants was conducted by Hofman, Hazebroek, and Valkenburg (1983) among Dutch newborn infants (*N* = 476) during the first 6 months of life. The trial randomly assigned the participants to a normal sodium diet or a low sodium diet starting immediately after birth. Researchers controlled the distribution of food for all of the neonates during the study period, and parents were encouraged to supplement with breast feeding when appropriate. The study found a positive correlation of sodium to blood pressure elevations during the first 6 months of life.

A long-term follow up of this cohort of children (*N* = 167), was performed 15 years later by Geleijnse et al. (1997). Researchers determined that there were no significant differences in the body height, weight, and body mass index of the study group. Physical activity, smoking, and alcohol consumption were equally distributed across the participants. Results showed that the participants who were exposed to the low sodium diet the first 6 months of life maintained a lower diastolic and systolic blood pressure than the children of the high sodium group. These data agree with the Barker hypothesis which linked early episodes in fetal and neonatal development to risk of diseases later in life.

Individual Preference of Drinking Water

In the United States, sales of bottled drinking water exceeded 10.5 billion dollars in 2009 despite an economic downturn. The choice between bottled water, public water, and private well water is influenced by factors ranging from water taste to perception of a risk of contamination. How parents of young children choose water for drinking and food preparation is not clearly understood (Merkel, Bicking, & Sekhar, 2012).

In a study conducted by Merkel, Bicking, and Sekhar (2012), it was observed through survey sample (N = 143) that misconceptions regarding available water safety and quality influenced parental choice. Environmental concerns regarding the disposal of plastic water bottles into landfills have also impacted efforts to reduce 'carbon footprints' and many people are choosing to filter household water supplies and reuse bottles. Regardless of the reason for the water choice, the majority of survey respondents indicated that their physicians had not discussed their water supply and would like this topic to have been raised during well-child care visits.

In urban minority children and adolescents (N = 208), Huerta-Saenz, Irigoyen, Benavides, and Mendoza (2012) found that water drinking preferences and consumption patterns were driven by the perceptions of water quality. Bottled water was perceived to taste better, to be purer, clearer, and safer than tap water. Yet news organizations over the years have conducted blind comparison tastings of tap and bottled water. Each time tap water was rated higher than bottled water, thus challenging existing perceptions. While these tastings have not been performed under controlled conditions, and the taster may be influenced by the familiarity of taste, the suggestion remains that increased consumption of bottled water may not be driven by taste entirely, but rather influenced by media and advertising in the shaping of consumer behavior.

An influence to the perception of water safety may be due to differences in government reporting of water quality. The Environmental Protection Agency (EPA) is charged with overseeing the protection and reporting of tap water supplies. This makes information on chemical and microbiological quality of tap water easily available for the public. Bottled water supplies are overseen by the Federal Department of Agriculture (FDA) and although water standards through this agency mirror those of the EPA, the FDA does not have statutory authority to require that water bottling companies use certified laboratories for water testing, make public notifications, or label bottled water contents regardless of violations. Lack of information on the contents of bottled water combined with marketing images of purity may foster a perception of water safety. Commercially bottled water is currently the second largest commercial beverage category in the United States, second only to carbonated soft drinks. As parents choose to purchase bottled water due to misconceptions of tap water quality or safety in their home it may present an unnecessary financial burden (Huerta-Saenz, Irigoyen, Benavides, & Mendoza, 2012).

Development of Preference for "Salty Taste"

Arguelles et al. (2007), pointed to a perinatal influence on salty taste development by using a meta-analysis to establish a relationship between adolescents (N = 72) whose mothers reported significant vomiting during the 1st trimester of gestation and a lower detection threshold for sodium, or a higher sensitivity to salt. Researchers also note a study by Crystal and Bernstein which found a preference for salty foods in college students (*N* = 169), of mothers who reported morning sickness during pregnancy.

Stein, Cowart, and Beauchamp (2012), used a prospective study to examine the development of salty taste acceptance throughout life being related to dietary experience in human infants (*N* = 61). This study raised concerns of the future dietary choices made by these individuals later in life related to this experience which may have cumulative effects elevating blood pressure. The longitudinal study found that dietary experiences of healthy infants exposed to starchy table foods were expressed in preferring salty solutions by the age of 6 months. These same infants were more likely to lick salt from the surface of foods by preschool age and tended to be more likely to eat plain salt. Findings suggested that early dietary experiences were pivotal in shaping salty taste responses in infants and young children.

A study conducted by Bartoshuk, McBurney, and Pfaffmann (1964) with 11 subjects using adapting solutions during daily sessions over the course of 10 days to determine if there was an adaptation to salty taste preference. The adapting solutions consisted of distilled water and nine solutions consisting of consecutively increasing levels of sodium chloride. The tongues of the subjects were rinsed prior to each tasting session with distilled water and in between each tasting to eliminate and residue or interference from saliva. Results indicated that the taste of the water and weak sodium chloride solutions were dependent on prior adaptations. The human tongue is ordinarily adapted to saliva which contains relatively low concentrations of salt. This may be one reason for the perception by some participants of water tasting flat or being tasteless, particularly in the instance of distilled water which may be reported as being bitter. Solution levels were concentrated to levels below or at the adapting, or rinsing, concentration were reported by participants to be bitter or sour. Solutions concentrated above the adapting concentration were reported by participants to be "salty", while solutions at the highest sodium chloride concentration were reported as sweet. Researchers confirmed with these preliminary observations that after adaptations to other chemicals water has very definite qualities of taste for the participant.

Arguelles et al. (2007) observed a significant correlation between blood pressure and salt taste perception in a Spanish population of healthy, normotensiven adolescents. Using a behavioral test consisting of a forced-choice staircase protocol, subjects received a series of successively paired solutions. Each solution was based on distilled and deionized water and each solution was successively more concentrated with a stronger sodium chloride solution. Subjects were given pairs of samples to taste. One of each pair was the base solution and the other contained a sodium solution. The first pair presented contained the highest sodium chloride solution and the base. Each pair was presented twice, as subjects correctly identified the salty solution. A new pair of less salty solution and base solution was presented for comparison. A failure to identify the salty solution in each pair resulted in a reversal in the presentation of the next solutions offered and the more intense stimulus was offered. The procedure continued until three reversals occurred. Results indicated that a higher SBP in the subjects led to the need for a higher threshold of sodium in order for the participant to detect “salty taste”. This study suggested a common or related cause for sensitivity to the taste of salt and blood pressure.

In summary, this chapter included a review of literature focusing on pathophysiology of sodium and fluid retention relative to hypertension in children. Federal and State Policies regarding safe drinking water were examined, along with taste preferences for drinking water resulting in a preference for a “salty taste”. The next chapter highlights nursing implications for research, policy, education and practices.

CHAPTER 3: DISCUSSION, LIMITATIONS AND IMPLICATIONS

Hypertension is a multifactorial disease involving genetics, environment, and behaviors. According to the Centers for Disease Control, nearly one in three U.S. adults has hypertension, and half of those do not have their condition under control. Hypertension is known to be a major contributor to cardiovascular disease in the United States and it is the leading cause of death, disability and health care costs. The major contributor to hypertension as a public health issue is excess dietary sodium (Gunn et al., 2012)

Fundamental links between sodium intake and high blood pressure levels have been well established. Reduction of dietary sodium intake for the prevention and control of hypertension is supported by numerous scientific bodies and professional health organizations including the American Heart Association, the American Medical Association, and the American Public Health Association. A reduction of systolic blood pressure by an average of 5 mmHg in a population can lead to an estimated reduction of 14% in stroke deaths and a reduction of 9% in coronary heart disease deaths (Gunn et al., 2012). Restriction of dietary salt has been shown to lower blood pressure in 15% to 42% of normotensive participants and 28% to 74% of hypertensive participants and as such, a dietary strategy aimed at population groups can have a substantial impact on overall cardiovascular health and blood pressure levels (DeCrane, 2004).

Sodium content in water supplies is a relevant factor in dietary sodium intakes, particularly in Florida. Residents who use wells to provide water for their personal use may not be aware of the sodium content. Many people believe that treatment of their water supply with use of a water softening system for the treatment of minerals, or what they may refer to as hardness, is sufficient. In fact, a water softening system can as much as triple the sodium content of the water during treatment because the primary component of treatment is salt for filtration.

In the most recent U. S. Census (2013), rural is defined as an area with a population density of less than 100 persons per square mile. The Florida State Department of Health (2005) estimates 1,172,421 people live in rural Florida. Based on the estimate that 21% of Florida's residents are under the age of 18, this translates to 246,209 children living in areas that are considered rural and are likely to using private water wells for drinking water. Water that is high in sodium may be an unsuspected cause of cardiac decompensation.

Many studies reference an increase of 2 to 5 mmHg in blood pressure in response in children to high sodium content in water supplies. Differences such as this in an individual have little meaning; a difference such as this in an aggregate can be significant from a public health viewpoint (Pomrehn et al. 1983). Directing efforts to reduce dietary sodium intake through reduced sodium drinking water aimed at high risk populations such as children in rural areas can have a significant impact on overall cardiovascular health and blood pressure levels thereby reducing clinical and public health burdens of cardiovascular disease.

The literature regarding sodium in drinking water and hypertension is conflicting. On one hand, Tuthill and Calbrese (1979, 1981), Tuthill, Sonich, Okun, and Greathouse (1980), Hofman, Valkenburg and Vaandrager (1980), Hofman, Hazebroek and Valkenburg (1983), Pomeranz, Korzets, Vanunu, Krystal and Wolach (2000), and Pomeranz, Dolfin, Korzets, Eliakim and Wolach (2002), report that sodium levels in drinking water have a direct effect on hypertension in children. Khan et al. (2011), found a correlation of high salinity drinking water and hypertension in pregnancy. Geleijinse, Hofman, Witteman, Hazebroek, Valkenburg and Grobbee (1997), reported that high sodium intake in childhood preempts hypertension in later life. The exact physiology is not known. Cooper, Soltero, Liu, Berkson, Levinson, and Stamler (1980), and Robertson (1984), indicated there are metabolic changes. While yet other researchers such as Stein, Cowart, and Beauchamp (2012) believe that a preference in taste leads to a lifelong preference for foods that are higher in sodium.

Conversely, studies by Faust (1982), Pomrehn, Clarke, Sowers, Wallace, and Lauer (1983), Lackland, Weinrich, Wheeler, and Shepard (1985), Welty et al. (1986), and Armstrong et al. (1982) indicated either an absence of a direct correlation of increased sodium levels in drinking water and the development of hypertension or increases which were so small as to be inconsequential. Gillium, Elmer, and Prineas (1981), contended insufficient data was available to state a finding with confidence.

Gaps in the Literature

In completing this review, several gaps were noted in the literature. Extensive literature has been dedicated to dietary sodium as a contributor to hypertension, yet very little attention has been paid towards drinking water as a source of dietary sodium. The WHO (2005) acknowledges that sodium content in water supplies is an international concern yet few studies exist which address the health effects. Few studies have been longitudinal in nature. A lack of information on lasting effects on infants and children exposed to contrasting sodium levels does not allow sufficient evidence for absolute confidence to the deleterious effects of sodium content in drinking water supplies.

Salt sensitivity has been found to be prevalent among African Americans, persons with hypertension, and persons with a family history of hypertension. Technique to determine salt sensitivity is difficult to perform on a population and studies assessing salt sensitivity have not been addressed at this level (DeCrane, 2004). More studies directed at nursing interventions regarding education of communities with high sodium content in drinking water supplies need to be researched and written. Awareness among primary health care providers needs to be heightened on sodium content in drinking water supplies as a contributor of the development of hypertension.

As a novice, attempting to determine if chronic exposure to elevated levels of sodium in drinking water is harmful requires further study. Adequate controls for variables that are potentially confounding such as body size, psychosocial stress, and other diet related factors cannot be readily achieved and conflicting results have been reported. Other variables such as sodium excretion and metabolism in arid and hot conditions should be considered in analyses.

Research

Based on this review and the gaps in the literature, the following are potential areas or future research

- Qualitative studies on taste development and a preference for “salty taste”.
- Correlation of sodium and high blood pressure in children.
- Examination of high risk populations for hypertension and a relationship to genomics.
- Environmental studies examining the pervasiveness of saline seep, in particular ocean water, into fresh water tables in Florida.
- The relevance of current understanding of levels of EPA standards nationally and locally with regard to standards in drinking water.
- Quantitative studies focusing on nurses understanding of the relationship of sodium and hypertension in children.
- Education strategies that would be most effective for parents and nurses

Nursing implications from this integrative review include suggestions for future research studies, policy, education, and clinical practice. Each of the following areas requires further consideration:

Policy

The findings from this thesis include a review of multiple policy guiding documents which often conflict on their recommendations. For example, the United States Department of Health and Human Services has issued dietary guidelines calling for a reduced dietary sodium intake every 5 years since 1980. Healthy People 2020 guidelines contain objectives toward building a healthy nation (Appel et al., 2012), as well as objectives targeting cardiovascular health to reduce the proportion of children and adolescents with hypertension. Objectives regarding nutrition include reducing the consumption of sodium in the population aged two years and older, and to increase the proportion of physician visits made by all child or adult patients that include counseling about nutrition or diet (Healthy People 2020, 2013). While trying to meet these objectives, conflicting information concerning maximum allowable sodium levels in available drinking water supplies are expounded by the USEPA, in conflict with the Florida DEP. Much of the information supplied by all parties conflicts with the WHO recommendations. Likewise, the American Academy of Pediatrics does not specify a type of water to use in formula preparation. For example, recommendations of the FDA are for non-sterile bottled water or water boiled for 1 minute and then cooled. The CDC recommends that caregivers use non-fluoridated tap water or low fluoride bottled water (Huerta-Saenz, Irigoyen, Benavides, & Mendoza, 2012).

In respect to future policies, current ones need to be further evaluated for relevance, effectiveness, and outcomes. Then, based on these findings, information needs to be disseminated to health professionals as well as state and local health departments to develop consistent policy and disseminated in a manner that is understandable by consumers and health professionals. Cultural preferences and health literacy levels need also to be addressed in dissemination of policies regarding sodium content in drinking water and sodium level intake by humans of varying ages, size and gender.

Education

The findings of this integrative review have several implications for nursing education. First and foremost is the correct technique for taking a blood pressure measurement in a child. Hypertension is difficult to diagnose in children and as such often is undiagnosed. Minor pathological signs or alterations during the early years of life may be significant markers or tracking signals in the development of hypertension, therefore monitoring them as tools for identifying subjects who could be treated prophylactically or advised about healthy habits early on would be beneficial (Arguelles et al., 2007). Education of nurses regarding the effects of sodium, and exposure to sodium in drinking water in a vulnerable population such as children is imperative to early recognition and treatment of hypertension. Again, it is important to take into consideration the cultural and linguistic preferences of targeted consumers. Suggested topical areas to integrate into nursing education:

- Defining hypertension in children (Appendix B).

- Accurate procedure for obtaining blood pressure measurements in children (Appendix C).
- Calculating the blood pressure in children (Appendix D).
- Understanding the long term consequences of hypertension in children.

Practice

Nursing implications related to practice that emerge from this review are discussed in the next few paragraphs. Population studies of epidemiological variations in health related behaviors are indicative of an increased rate of hypertension in the young, creating several challenges which face clinicians regarding children and hypertension. These challenges include the early detection of hypertension, distinguishing primary from secondary hypertension, the skill of examining children for hypertension related risk factors and target organ damage, as well as applying interventions to control blood pressure and encouraging preventive lifestyle changes (Falkner, 2010).

Primary prevention.

Primary prevention focuses on health promotion which includes public and individual education to promote awareness of early detection of elevated blood pressure levels. The U.S. Department of Health and Human Services (2005) recommends that children over 3 years of age that are seen in medical care settings should have their blood pressure measured at least once during every health care episode. Children under the age of three should have their blood pressure measured in special circumstances. Special circumstances; such as prematurity, a very low birth weight, neonatal complications which required intensive care, congenital heart disease, recurrent urinary tract infections, hematuria, proteinuria, known renal disease, urologic malformations, family history of congenital renal disease, a solid organ transplant, malignancy, bone marrow transplant, or treatment with drugs known to raise blood pressure. Vessey et al. (2001) noted that despite many risk factors for hypertension that begin in childhood there are no recommendations regarding blood pressure screenings with education in schools available from the American Heart Association, the U.S. Department of Health and Human Services or Education, nor from the National Association of School Nurses. As such, screenings in children under 6 years of age are not routinely performed as part of primary care for children in the U.S.

The role of the school nurse in conducting health education screenings on children is influential in identifying unrecognized disease or defects through the application of tests, examinations, or other procedures. Many school aged children are less likely to see their primary care provider for well-child care compared to younger children who are not in school, particularly those from families of lower socioeconomic backgrounds. This leaves the school nurse with a responsibility to apply screening protocols in an attempt to help identify the presence of health concerns in seemingly asymptomatic children.

Primary hypertension in is becoming more prevalent in older children. Clinical manifestations in children with systemic hypertension often are asymptomatic. A thorough history and physical examination should be obtained for a child. Positive family history of hypertension is a risk factor that is difficult for most youth to answer in a clinical situation, therefore parents should be made aware of their own blood pressure status and communicate this information to the child or to the school nurse. Exact contributions of lifestyle with genetics and family history are unknown. There is abundant evidence that hypertension in adults may begin during infancy. Genotype for hypertension continues to be nurtured by the environmental choices or exposures throughout life (Vessey et al., 2001). Health related behaviors such as physical inactivity, unfavorable dietary patterns and excessive weight gain are known factors which increase the risk of developing hypertension (U.S. Department of Health and Human Services, 2005). Findings from this integrative review lead to the suggestion for the following clinical assessments for primary prevention in children.

- Identifying children at risk for the development of hypertension through health screenings.
- Educating and screening early diagnosis of hypertension in school and developmental clinical visits
- Obtaining and calculating accurate blood pressure measurements in children using consistent measuring techniques.
- Assessing for environmental health hazards including the quality of available drinking water sources and the associated mineral content.
- Providing education for parents and children regarding healthy food choices, preparation, and how to read and understand food labels.
- Teaching parents and children adequate dietary intakes, including that for sodium, and the consideration of all dietary sources including drinking water.

- Encouraging lifestyle behavior modifications if the form of regular aerobic exercise

Secondary prevention.

Secondary prevention focuses on screening and early diagnosis often before clinical manifestation. Early identification of increased blood pressure allows health concerns to be carefully monitored and documented over time, and where appropriate, interventions may be initiated and earlier interventions have the potential to diminish the severity of pathologic changes (Vessey et al, 2001). The American Academy of Pediatrics (2012) suggests that working with local public health officials and community health practitioners to expand school health nursing care of children to include screening for hypertension. Effective strategies for secondary prevention of hypertension in children are listed below.

- Assess for comorbidities related to secondary hypertension, or a family history of hypertension.
- Promote repeated monitoring of blood pressure in the primary care setting and through coordination with the public school system and local health department, ambulatory monitoring may be an option.
- Perform additional diagnostics such as urine and blood tests to evaluate blood sugar, kidney function and blood cell count, ultrasound to check kidney function or echocardiogram to evaluate cardiac blood flow.
- Encourage use of a diet journal as a tool to track sodium intake.

Tertiary prevention.

Tertiary prevention focuses on the effective management of a diagnosed condition to stop or slow the progression of the disease process. The goal is to stop progression, decrease or moderate the disability, and begin the rehabilitative process.

Tertiary interventions for hypertension in children include the following:

- Educate parents and children to manage hypertension and the associated symptoms
- Educate parents and children on dietary and lifestyle modifications focusing on the reduction of sodium, weight control, and encourage physical activity.
- Proper use and evaluation of antihypertensive medication effectiveness.
- Educate the parent and the child to identify sequelae effects of hypertension, or side effects of treatment to enhance outcomes.

Limitations

Limitations of this integrative review include the novice status of this writer. This first attempt to disseminate the available information and critique complex research studies proved limiting for a beginner. Research included only results printed in English and findings may have been broadened by the use of international studies. Superficial understanding of the mechanisms driving the development of hypertension by this clinician also affected the outcomes of this work product. In summary, this chapter noted gaps in the literature and highlighted implications for nursing along with limitations of this integrative review paper.

APPENDIX A: CHART OF ARTICLES

United States

Author(s) Date & Location	Title	Population Sample & Setting	Intervention Procedure	Sodium Source & Level	Specific Findings
Tuthill & Calabrese 1979 Massachusetts	Elevated Sodium Levels in the Public Drinking Water as a Contributor to Elevated Blood Pressure Levels in the Community	600 White High School Sophomores (300 from each community) - In 2 separate schools in adjacent communities, about 150 students were screened per day on successive Mondays and Tuesdays in late March of 1977. Weather	- Empirical study - Adolescents sat while filling out the questionnaire for a minimum of 6 minutes and waited a maximum 25 additional minutes to move through 3 stations where a causal blood pressure was taken on the left arm at each station which was occupied by different nurses with no knowledge of the previous readings - Drinking water samples collected from each school on the each day of the study with standardized collection	- Two geographically contiguous communities in Massachusetts: - High Sodium Community has 108 mg/L - Low Sodium Community has 8 mg/L	- Averages are based on three causal blood pressures for each individual - High Sodium Community: Females Average Systolic = 113.49 Diastolic = 67.80 Males Average Systolic = 123.11 Diastolic = 65.17 - Low Sodium Community: Females Average Systolic = 108.38 Diastolic = 62.69 Males Average Systolic = 119.54

		conditions were similar in both communities and both study days required the entire school day to make the collections.	methods. Values of these samples was consistent with the average values reported for the communities - Screening conducted by the same 4 nurses for both communities.		Diastolic = 62.48 - Mean Difference: Females Average Systolic = 5.11 Diastolic = 5.11 Males Average Systolic = 3.57 Diastolic = 2.69
Tuthill, Sonich, Okun & Greathouse 1980 Texas and Oklahoma	The Influence of Naturally and Artificially Elevated Levels of Sodium in Drinking Water on Blood Pressure in School Children * Specifically	- 337 seventh grade children - Seventh graders from 2 separate communities which used well water were compared in the study. - High sodium community of Texas	- Empirical studies - Four nurses were used to obtain 3 consecutive blood pressure measurements from each child in 3 separate stations with a different nurse assigned to each station. - The nurses could not see the previously recorded measurements - Screening included weight, height, pulse and blood	- Two separate communities were compared. - High Sodium community: Texas with 275 mg/L - Low Sodium community: Ohio with 25 mg/L	- No significant difference in the mean blood pressures between the two communities for either sex in diastolic or systolic pressures was found. - A difference was found in the male diastolic pressure reading which were opposite of the hypothesis reflected in an almost 2mmHg increase in the low sodium community. - Confounding factors may include the adverse event of a Tornado strike

	the Texahoma Study documented within this article.	participated with males (*n* = 114), and females (*n* = 114) - Low sodium community of Ohio participated with males (*n* = 63) and females (*n* = 46) - Both communities had similar characteristics of population size, median family income, education levels, ethnicity, employment fields and	pressure. - Questionnaire regarding recent last meal and smoking habits. - Several weeks later the students completed a 24 hour diet diary and provided a home drinking water sample and a first morning urine specimen		to the lower sodium community the night before the scheduled blood pressure readings. It was reported that many of the children suffered poor sleep and stress from the night prior to the readings. This event was not discovered until more than halfway through the exam and the only choice was to complete the exam and comparison.

		unemployment percentages. The major variation was in drinking water sodium content			
Tuthill, Sonich, Okun & Greathouse 1980 Ohio	The Influence of Naturally and Artificially Elevated Levels of Sodium in Drinking Water on Blood Pressure in School Children * Specifically the Ohio Water Softener Study documented	- 326 seventh graders who lived in homes with varying drinking water sodium levels - Ohio community with marked differences in available water within the community itself. - Differences included homes with water	- Children were weighed, measured and screened for blood pressure in the same manner as the Texahoma Study above from this same article.	- Water softener system: Sodium = 7-254 mg/L Males (*n* = 47) Females (*n* = 27) - Town district tap water: Sodium = 2-27 mg/L Males (*n* = 82) Females (*n* = 104) - Military base supplied water: Sodium: 175-254 mg/L	- Water softener system: Males average: Systolic = 102.9 Diastolic = 59.9 - Females Systolic = 103.4 Diastolic = 64.0 - Town district tap water: Males average: Systolic = 104.1 Diastolic = 60.0 - Females average: Systolic = 98.8 Diastolic = 63.9 - Military base supplied water:

	within this article.	softener systems, homes with town supplied tap water, a military base with an independent water treatment process, and an adjacent city with a different water supply - Total studied males (n = 162) - Total studied females (n = 164)		Males (n = 17) Females (n = 23) - Next City: Sodium = 19-23 mg/L Males (n = 16) Females (n = 10)	Males average: Systolic = 99.4 Diastolic = 59.3 - Females average: Systolic = 99.4 Diastolic = 64.2 - Next City: Males average: Systolic = 98.3 Diastolic = 57.0 - Females average: Systolic = 95.8 Diastolic = 63.5
Cooper, Soltero, Liu, Berkson, Levinson, & Stamler	The Association Between Urinary Sodium	- 73 children from ages 11 to 14 from 2 different parochial	- Empirical study - Diet was not altered - Groups of 6 – 10 children	- Sodium source was determined through data collection of dietary recall	- Through diet records and direct questioning it was determined that the children from school A tended to eat away from home on Friday and Saturdays, particularly eating in fast

1980 Illinois	Excretion and Blood Pressure in Children	schools in Chicago, Illinois completed the study - School A (n = 45) Children of African American decent Males (n = 19) Females (n = 26) - School B (n = 28) children of Eastern European decent Males (n = 12) Females (n = 16)	were instructed on the collection procedure for 24 hour urine samples - Children were provided cases and containers for the urine samples - Urine samples were collected over a period of 1 week - Urine samples were evaluated for sodium, potassium, and creatine - Height and weight were measured in light street clothes and shoes - Blood pressure was measured after sitting in a quiet room for 5 minutes with arm resting at heart level Blood pressure was assessed		food restaurants and urinary sodium excretion was increased correlating to those days - Height, weight, pulse, age, sex and race were considered simultaneously to determine significance in the independent role of sodium - The mean 24 hour excretion of creatine had the strongest relationship to blood pressure readings

			by 2 observers for each child who were certified and trained in the Hypertension Detection and Follow-up Program. Average of 4 readings was used for analysis - Measurements were made at the beginning and end of the collection week.		
Calabrese & Tuthill 1981 Massachusetts	The Influence of Elevated Levels of Sodium in Drinking Water on Elementary and High School Students in Massachusetts * Specifically the study on tenth graders	- 606 tenth grade students from 2 adjacent communities - Children attended 2 different high schools in adjacent communities. - High sodium community (*n* = 300)	- Empirical studies - Screenings were scheduled to accommodate 150 students on each of four days. 2 successive days in one community and the same two days of the following week in the second community - 4 nurses collected all of the blood pressures using a 45 minute time rotation and collecting 3 readings from each student	- Two separate and adjacent communities were evaluated - The high sodium community water supply was 107 mg/L - The low sodium community water supply	- Children from the high sodium water supply community revealed an increased blood pressure consistently for both sexes but was more apparent in the comparison of females. - Mean systolic and diastolic for females from the high sodium community was 113.5/67.8 mmHg compared to 108.4/62.7 mmHg - Differences were upheld with potentially confounding factors such as dietary sodium intake, and other

	and town supplied drinking water	- Low sodium community (n = 306)	- Screening took place a minimum of 45 minutes after a meal, and children did not attend gym class at least one hour prior to screening. - Efforts were made to keep the students calm and quiet, they were seated a minimum of 6 minutes while completing questionnaires prior to the screenings which were taken on the left arm at three separate stations - Each successive nurse was blind to the previous readings. - Information was obtained on weight, height, length of residence in town, smoking history, recent weight gain or loss, eating habits, health status, occupation and	was 8 mg/L	water factors - A replication of this study was performed on n = 346 third graders in the high sodium community and n = 262 from the low sodium community. Using the same procedures as with the tenth graders, similar patterns were found and upheld the findings of the tenth grade study.

			education of family's main wage earner, and current use of blood pressure medication.		
Tuthill & Calabrese 1981 Massachusetts	The Influence of Elevated Levels of Sodium in Drinking Water on Elementary and High School Students in Massachusetts * Specifically the study of fourth graders and experimental sodium levels in bottled water	- 552 Fourth graders from 2 adjacent communities in Massachusetts - Children attended 7 different schools - Children were divided into 3 groups and were blind to the type of water being provided - Communities chosen were of equal	- Trial was 3 months - Children were matched by sex, school, and baseline blood pressure - Children were randomly allocated 3 types of bottled water. The water supplied was used as drinking water and for the preparation of foods and beverages - Nursing personnel recording the blood pressures were blind to the type of bottled water being used by the child. - Water was bottled and delivered to the home every 2 weeks during the study. Each batch was monitored for	- 3 types of bottled water were used: 1) with high sodium from their own community distribution (110 mg/L) 2) low sodium bottled water from the distribution system of the comparison community with sodium added to be equal to the level of the high sodium community water (8 mg/L)	- The low sodium group of girls had a consistently higher blood pressure decline than the boys in all follow up periods. Systolic was 1.7 to 2.3 mmHg and diastolic was 3.4 to 4.6 mmHg. - Female sensitivity of blood pressure reduction in response to sodium reduction in drinking water was a clear finding

		populations, growth, socioeconomics, and ethnicity. - High Sodium community Males (n = 160) Females (n = 152) - Low sodium community Males (n = 130) Females (n = 110)	consistency. - All children had baseline measurements obtained one week prior to the initiation of the study. Blood Pressure measurements were monitored on a biweekly basis throughout the study. - Standardized screening procedures were used and 3 measurements collected at each screening. - In addition, first morning urine specimens and two day diet recall records were collected prior to study commencement, and monthly throughout study. - Further data collected included height and weight changes and dietary habits	adjusted to reach 110 mg/L 3) Low sodium water bottled from the comparison community with no sodium added (8 mg/L)	

			during the study period - Questionnaires provided information on socioeconomic status, time living in the area of water distribution, infant feeding habits (breast versus formula milk) family history of high blood pressure and every two weeks the parents reported extent of adherence of the child.		
Tuthill & Calabrese 1981 Massachusetts	Drinking Water Sodium and Blood Pressure in Children: A Second Look	- 607 Third grade children - 2 geographically contiguous communities in Massachusetts - demographics included similarities in	- Empirical study - Procedures were the same as the Massachusetts studies preceding this. With the addition of nurses traveling to capture reading on the same days to negate diurnal variations. - Controlled variables were history of familiar high blood	- High sodium community contained sodium levels of 120 mg/L - Low sodium community contained sodium levels <20 mg/L	- The high sodium community had a mean difference to the low sodium community of: Males: Systolic increase of 3.2 mmHg Diastolic increase of 2.5 mmHg Females: Systolic increase of 2.7 mmHg Diastolic increase of 4.0 mmHg

		town size, median income, education, and ethnic composition - Prime difference was the water sodium levels with a difference greater than 100 mg/L - High sodium community (*n* = 345) - Low sodium Community (*n* = 262)	pressure, length of residence in town, medication being taken by the child, feeding habits as an infant, education level and occupation of the main wage earner in the family. Height and weight data were also compiled. - Dietary diary of 24 hour recall was coded using the Nutritive Value of American Foods supplied by the USDA. - Urine samples were collected as first morning clean catch		- This study bore similar results to that of the previous study of tenth graders studied in the same communities - Increased blood pressure appears to represent a general shift of the whole group toward higher blood pressure levels rather than a small group of susceptible persons exhibiting a response
Gillium, Elmer & Prineas	Changing Sodium Intake in Children.	- 10,301 student in Minneapolis, Minnesota	- Empirical study - All 80 Families were given	- Dietary sodium was to be controlled by	- 11 people from the intervention group attended the meetings consistently and 16 completed urine

1981 Minnesota	The Minneapolis Children's Blood Pressure Study	(first, second and third graders) were surveyed for blood pressure, height, and weight. - Those over the 95th percentile (>130/90) were studied with a reduction of dietary sodium - 80 families were contacted and agreed to participate on a 1 year study - Control Group (n = 39)	initial consultation - Urinary samples height, weight, skinfold thickness and blood pressure were obtained at the start and completion of the study - Control group was not contacted for 1 year Intervention group involved both parents and children in 4 biweekly intensive 90 minute lecture demonstration sessions followed by bi-monthly sessions over the course of the year of 90 minute maintenance sessions - Each session incorporated 60 minutes of instruction which separated parents and children for specific lessons and then reuniting them for 30	the parents to keep sodium under 70 mmole per day for each family member -Measurement obtained through journals and scoring of sodium content computed using the U.S. Department of Agriculture Handbook No. 8.	collections. - In one year, both groups showed similar increases in height and weight - One year later, no significant differences in blood pressure between the groups was noted - Small sample size is not sufficient to exclude small differences with confidence - Sodium intake among children among the active intervention group who participated were reduced by approximately 40% to near goal levels by 6 mos and 1 year. No adverse physical or behavioral effects were identified.

		- Intervention Group (n = 41)	additional minutes of lecture		
Faust 1982 Michigan	Effects of Drinking Water and Total Sodium Intake on Blood Pressure	- Cohort of 295 persons from rural Michigan - Affected area had 1003 residences in 267 households. - 458 residents agreed to attend a health screening, ultimately 195 persons were screened (29.4% participation from the community)	- Empirical study - Water samples were collected from pretreatment water supplies. - The location of the water supplies was correlated with the location of the site where salt for road deicing was stored and considered a source of contamination - Mean length at residence was 72.1 months. - Dietary sodium was estimated to be 3980 mg for residents under 18 years of age, and 3368 mg for residents over 18 years of age. - Participants reported using	- Two separate wells. One contained 251 mg/L of sodium and the other contained 273 mg/L - Area investigated ranged of 15.0 to 900 mg/L when water was sampled before it entered the house. - 92 of the 268 houses sampled used water softeners to treat the water as it entered the	- Levels of sodium in drinking water were not found to be related to blood pressure levels or presence of hypertension - A relationship was found between 24 hour sodium excretion and mean blood pressure in both adults and children. - With the small sample size and possibility of inaccurate measurements, and dietary recall, this study does not rule out the possibility of a relationship between chronic high sodium in drinking water and blood pressure levels. It does offer evidence of the absence of a direct correlation of hypertension in a population to diverse drinking water sodium intakes.

			bottled water for 1 to 5 months prior to the screening	home. The water softeners added an average of 19.9 mg/L of sodium to the water supplies in these homes.	
Pomrehn, Clarke, Sowers, Wallace & Lauer 1983 Iowa	Community Differences in Blood Pressure Levels and Drinking Water Sodium	- Initial survey of over 2,000 school children in eight Iowa communities - Detailed study of over 200 children and their families in four communities. - Children studied were between the 2nd	- Empirical study - Blood pressures were measured 4 times per day per child. 2 measurements in the morning and 2 in the afternoon - The child's blood pressure was taken after sitting quietly for 5 minutes. - The measurements were conducted over consecutive days, but no variables are listed such as if there is a	Initial survey - Drinking water sodium levels varied from <10 mg/L to >300 mg/L Detailed survey - Municipal water source compared to municipal water source with water softening system for home use	- Blood pressure varied amongst measurements in residents of low sodium communities. For example; there was an approximate 4 mmHg difference in mean blood pressure reading between the 8 communities and that did not correlate with the sodium level of the water. - Surveys do not substantiate previous reports indicating a positive association of drinking water to blood pressure levels

		and 5th grades	difference on the day of the week etc.		
Lackland, Martin, Weinrich, Wheeler & Shepard 1985 South Carolina	Sodium in Drinking Water in South Carolina	- 825 households in South Carolina were selected to participate with a representative of 1 household member of 18 years of age or older from each.	- Empirical study - The Hypertension Detection and Follow-up Program blood pressure methods was used to certify and train interviewers in blood pressure measurement technique - Interviewers were certified and trained in questionnaire administration and dietary recall procedures - Interviewers selected proper cuff sizes and took 3 consecutive blood pressure readings - Respondents taking blood pressure medications were excluded	- Interviewers obtained 24 hour diet recall information for later evaluation of sodium intake - Drinking water groups were divided into 2 groups. One of less than 20 mg/L and one of greater than 100 mg/L and drinking water consumption was estimated at one liter per day for dietary calculations	- Group with less than 20 mg/L were estimated have a total dietary sodium intake average of 2058 mg, and less than 1% of that came from water. - Group with greater than 100 mg/L were estimated to have a total dietary sodium intake average of 2341 mg, and drinking water contributed 8.5% of total sodium - No significant differences were found in blood pressure results from the high to low sodium groups

			- A 50 mL water sample was obtained from each household to determine sodium content		
Welty et al. 1986 Arizona	Effects of Exposure to Salty Drinking Water in an Arizona Community	- Total participants (*n* = 717) Papago households (*n* = 72) Non-Indians households (*n* = 117) 46% of those were >25, 37% were aged 6-24, and 17% were less than 6 years old. - High sodium participants:	- Empirical study - Participants, age > 25, interviewed for health risk factors, water consumption, dietary sodium and calcium intake, height weight, blood pressure, and urinary sodium and potassium levels. - Participant age 6 – 24 demographic information was obtained and body measurements - Children under the age of 6 only demographic information was obtained - Questionnaire used was modified from the CDC Health Risk Appraisal	- 440 mg/L of sodium was estimated for the Gila Bend community	- The Gila Bend population was not found to have higher blood pressures than the reference population. - Lack of association may be attributable to a higher environmental temperature leading to a higher metabolism excretion through sweat, or due to a small proportion of individuals sensitive to dietary sodium, imprecise measurement of dietary intake, measurement error in blood pressure determination or lack of a true biologic relationship between sodium intake and blood pressure.

		Papagano (76%) Non-Indian (44%) - The rest of the participant drank bottled water, effectively treated water or water from other communities with lower sodium levels	questionnaire and the Second National Health and Nutrition Examination Survey (NHANES II) and included socio-demographic information, medical occupational and dietary history or the average weekly intake, and health risk factors. - Food models were used to determine serving sizes and dietary manuals were used to determine amounts of dietary sodium and calcium - Three successive blood pressure measurements were taken at least 5 minutes apart with participant sitting - Participants with fevers were excluded until they became afebrile		

			- Quetelet's body mass index (BMI) was used to calculate obesity - Overnight urine specimens were obtained and sent to the CDC for evaluation of sodium and potassium - Water samples were obtained and consideration of filtration methods used for potability was considered.		

International

Author(s) Date Location	Title	Population Sample & Setting	Intervention Procedure	Sodium Source & Level	Specific Findings
Hofman, Valkenburg & Vaandrager 1980 Netherlands	Increased Blood Pressure in Schoolchildren Related to High Sodium Levels in Drinking Water	- 348 school children 7.7 – 11.7 years old - Three demographically consistent communities in the Netherlands. Parents were found to have similar occupations	- Retrospective follow-up study - Adjustments were made for weight, height, pulse rate, age, family history of hypertension, and time of blood pressure measurement - Blood pressure readings were made by one observer who was not aware of differences in the sodium content of water - All blood pressures were obtained within a 2 week period - 2 consecutive blood pressure reading were taken	- Other than citing the areas of drinking water sodium to be either high or low, no mg/L are disclosed.	- After adjustments, differences in blood pressure elevations ranging from 1.8 to 4.0 mmHg in areas with high sodium drinking water supplies. - Girls and boys showed the same essential differences - A mean 24 sodium excretion were found to be somewhat higher in the long term exposure to low sodium water supplies. There were no differences found in the sodium-creatine ratio. Regression coefficients between the sodium excretion and the blood pressure readings were not found to be significant

			- Readings were taken on the left arm after at least 5 minutes of rest with the participant sitting - Sodium intake was estimated using urinary sodium excretion with a 24 hour urine sample		- Research findings support the hypothesis that sodium intake influences blood pressure and the association is measurable regardless of the amount of time the child was exposed to the high sodium water supply
Armstrong et al. 1982 Australia	Water Sodium and Blood Pressure in Rural School Children	- School children age 12 to 14 in six rural towns with varying water sodium levels Boys (*n* = 326) Girls (*n* = 309)	- Empirical Study - 3 day surveys were conducted at 6 high schools - With the class teacher and a survey team member, students completed surveys including demographic characteristics, diet including fluid intake, and lifestyle. - Height, weight, skinfold thickness, mid-upper arm circumference, pulse rate, and	- Rural areas 1.46 to 9..69 mmol/L - Low sodium rain water collections - Town water 1.5 to 11.6 mmol/day	- Water sodium levels were not found to have an effect on urinary sodium excretion - A significant positive relationship was found between the blood pressures levels and the pulse rate, body height, and weight, Quetelet's body mass index, mid-upper arm circumference, and skinfold thickness of triceps. - Adjusting for control of these variables no relationship between water sodium levels and blood

			blood pressure were measured and dietary records with 24 hour recall were collected - Observers collecting blood pressures were trained using training tapes and a timer. - Pressures were taken once while sitting for longer than 5 minutes and the second immediately after standing. Ambient room temperatures were recorded. - Boys participating in the study to supply two consecutive 24 hour urine collections. - Drinking water samples were collected by the children who did not use the main town water supply		pressure was uncovered
Hofman, Hazebroek &	A Randomized Trial of Sodium Intake	- Double blind trial conducted in the	- Empirical Study - Diets were randomly assigned	- Foods were prepared and supplied free of	- Average measurements of systolic pressures taken at 25 weeks indicated a 2.1 mmHg increase in the

Valkenburg 1983 Netherlands	and Blood Pressure in Newborn Infants	Netherlands - 245 newborn infants assigned a normal sodium diet - 231 newborn infants assigned a low sodium diet	at birth to be used during the first 6 months of life - Normal sodium group was almost 3 times more sodium - Systolic blood pressures were measured every month from the first week until the 25th week - Parents were encouraged to breast feed to supplement the formulas provided - Parents were advised to begin solid foods at the 13th week which was delivered to the home by the study nurse. - The study nurse recorded all amounts of formula and foods used by the parents - Mothers were responsible to	charge to the new parents. - Normal sodium foods contained what was commercially available during the study period. - Low sodium foods were prepared to have one third of the content in the normal sodium food.	normal sodium group to the low sodium group - Observations in the difference between blood pressures of the high and low sodium groups was significantly increased during the first 6 months of life agree with the view that sodium intake is causally related to blood pressure

			record anything outside of study protocols		
Robertson 1984 United Kingdom	Water Sodium, Urinary Electrolytes, and Blood Pressure of Adolescents	- Children in Scunthorpe Health District of the United Kingdom - Over 3000 children between the ages of 14 and 14 years 11 months were exposed to varying sodium content in water supplies, 2740 were examined Boys (*n* = 1394) Girls (*n* = 1346)	- Empirical Study - 2 state registered nurses were recruited and trained to take blood pressure measurements - First each child was weighed and measured, then the initial blood pressure was taken. A questionnaire was then filled out including the dietary preferences and 24 hour diet recall. A second blood pressure measurement was taken. - Boys were asked to provide a urine specimen for analysis and 769 boys complied.	- supply 1 = 105 mg/L - supply 2 = 50 mg/L - supply 3 = 15 mg/L	- No relationship between water salinity and systolic or diastolic blood pressure was found - A relationship of median blood pressures and urinary sodium excretion was well correlated to salt and fluid intake of meal immediately before the examination. - A relationship of blood pressure and urinary sodium concentration without a clear relationship to the sodium creatine ratio supports the study hypothesis that a ratio of salt to fluid intake rather than the total dietary sodium being relevant to the regulation of blood pressure
Geleijnse, Hofman, Witteman,	Long-term Effects of Neonatal	- 167 children (35%) of the original cohort	- Retrospective follow-up study - Measurement of differences in	- Original groups of either low sodium or	- Low sodium diet group blood pressures were lower by a mean of 3.6 mmHg systolic, and a mean

Hazebroek, Valkenburg & Grobbee 1997 Netherlands	Sodium Restrictions on Blood Pressure	of the double blind trial conducted in the Netherlands, titled, "A Randomized Trial of Sodium Intake and Blood Pressure in Newborn Infants" by Hofman, Hazebroek & Valkenburg (1983) agreed to participate in the follow up study. - 71 from the original low sodium group - 96 from the normal sodium diet group	blood pressure levels between the original diet groups. - Measurements taken on right arm, by 2 investigators while the participant was seated, after a minimum of 5 minutes rest. - 4 measurements were taken and the last 3 were averaged and used for analysis. - Body weight, height were measured and BMI was calculated. - Participants answered questionnaire on smoking, alcohol and drug use, medication use, physical activity, education, and diet information. Girls supplied information of onset of menarche.	normal sodium diet children up to the age of 6 months from the original study.	lower diastolic of 2.2 mmHg - Findings are suggestive that sodium intake in infancy may have long term consequences to blood pressure elevations later in life

			- Participants supplied an overnight urine sample		
Pomeranz, Korzets, Vanunu, Krystal & Wolach 2000 Israel	Elevated Salt and Nitrate Levels in Drinking Water Cause and Increase in Blood Pressure in Schoolchildren	- 3 groups of fourth and fifth grade schoolchildren in Israel - Group 1(n = 452) - Group 2 (n = 418) - Group 3 (n = 86) -There were no outstanding differences physical or daily activities of the children from the 3 respective regions	- Empirical study - The groups were matched by age, weight, and height - Detailed questionnaires were used to determine dietary food consumption of salt and filed out by the mothers of the participants - Blood pressure was measured in a sitting position after a period of resting for 25 minutes. - Urine samples were collected prior to blood pressure measurements	- Group 1 = high sodium of 49 and 196 mg/L respectively - Group 2 = low sodium of 25 and 49 mg/L respectively - Group 3 = low sodium of 25 and 35 mg/L respectively	- Daily dietary intakes of salt and potassium were found to be similar - Group 1 systolic pressure was 116 mmHg, Group 2 was 111 mmHg, and Group 3 was 107 mmHg. Group 1 MAP was 86 mmHg, group 2 was 83 mmHg, and group3 was 81 mmHg - The systolic blood pressure in group 2 also reflected a significantly higher mean than group 3 - Systolic blood pressure and mean arterial pressure reflected a significant increase between group 1 and groups 2 and 3.

Pomeranz, Dolfin, Korzets, Eliakim & Wolach 2002 Israel	Increased Sodium Concentrations in Drinking Water Increase Blood Pressure in Neonates	- Israeli neonates 2 months of age exposed to 3 levels of sodium in food sources over 8 weeks - Group 1 (*n* = 25) infants - Group 2 (*n* = 33) infants - Group 3 (*n* = 15) infants	- Empirical study - Weekly weight, height, head circumference, heart rate and blood pressures were recorded for 8 consecutive weeks in each infant - After the eighth week group 1 converted to a diet similar to group 2. - Follow-up blood pressure measurements performed at week 24 in 11 of group 1, 20 of group 2, and 7 of group 3. - Blood pressure was measured during sleep - Urinary sodium: creatine ratio determined during the initial 2 month period	- Group 1 formula diluted with low sodium mineral water concentrated at 32 mg/L - Group 2 formula diluted with high sodium tap water concentrated at 196 mg/L - Group 3, control group, fed breast milk	- All groups had equal increases in weight and height - There was no difference in heart rate between any of the groups for the entire study period - The blood pressures in group 2 were significantly higher from age 6 to 8 weeks as well as an increase in urinary sodium: creatine - Blood pressure values in group 1 increased similar to those of group 2 when measured at 24 weeks correlating with the increased sodium concentration in the formula - Increased sodium diet through drinking water concentrations results in increased blood pressure in neonates
Khan, Ireson,	Drinking Water Salinity	- Bangladesh's southwest	- Descriptive study	- Dry season estimates	- Estimated dietary sodium intake from drinking water in this

Kovats, Mojumder, Khusru, Rahman & Vineis 2011 Bangladesh	and Maternal Health in Coastal Bangladesh: Implications of Climate Change	coastal region with a population of 157,500 people -969 pregnant women were diagnosed with hypertension - Random sample of 343 pregnant women were studied between October 2009 and March 2010, what is considered dry season	- Water salinity data obtained from the Centre for Environment and Geographic Information System in Bangladesh. Data - researchers estimated a conservative water intake of 2 L/day per person - Direct estimates of salt water intake were made from analysis of 24 hour urine collection samples. - Routine measurements of all pregnant women at gestational week 20 include blood pressure and screening for proteinuria if they have elevated blood pressure or edema.	sodium intake from drinking water of 5 - 16 g/day Rainy season estimates sodium intake from drinking water of 0.6 – 1.2 g/day	population exceeded recommended limits. - Saline intrusion into the aquifer from multiple causes effected salinity levels in drinking water resulting in a prevalence of seasonal hypertension in pregnant women related to the drinking water salinity levels

APPENDIX B: DEFINING HYPERTENSION IN CHILDREN

A diagnosis of childhood hypertension begins with the identification of blood pressure as either normal or elevated. Defining hypertension in children takes into consideration age, gender, and height as opposed to the definition of hypertension in adults which is based upon clinical endpoints (Flynn, 2003).

A normal blood pressure for children has been defined by the National High Blood pressure Education Program (NHBPEP) as systolic and diastolic blood pressure below the 90th percentile for age; and, hypertension is diagnosed with a pressure greater than the 95th percentile for the child's age group. With height as a factor, the NHBPEP recommends that at least three consecutive abnormal readings, acquired on separate occasions, be obtained prior to making a diagnosis of hypertension in a child (Flynn, 2003).

APPENDIX C: ACCURATE PROCEDURES FOR OBTAINING BLOOD PRESSURE MEASUREMENTS IN CHILDREN

According to the U.S. Department of Health and Human Services (2005), correct measurement of the child's blood pressure requires a cuff that is appropriate to the size of the child's upper right arm be used. Appropriate cuff size is determined by an inflatable bladder width that is at least 40 percent of the arm circumference at a point midway between the olecranon and the acromion and the length of the bladder should cover 80-100 percent of the circumference of the arm. Dimensions for blood pressure cuff bladders for accurate measurements recommended by The U.S. Department of Health and Human Services (2005) are listed below.

Table 1 Recommended Dimensions for Blood Pressure Cuff Bladders

Age Range	Width (cm)	Length (cm)	Maximum Arm Circumference (cm)
Newborn	4	8	10
Infant	6	12	15
Child	9	18	22
Small Adult	13	30	34
Large Adult	16	38	44
Thigh	20	42	52

When taking the blood pressure, the correct cuff size is important. Likewise the bell of the standard clinical sphygmomaneter should be placed over the brachial artery pulse, proximal and medial to the cubital fossa, and below the edge of the cuff (U.S. Department of Health and Human Services, 2005).

APPENDIX D: CALCULATING THE BLOOD PRESSURE IN CHILDREN

Clinical formulas for calculation of systolic blood Pressure (SBP) and mean arterial pressure (MAP) in normal children which are currently being used to calculate SBP of the 5th percentile at the 50th percentile is to multiply 2 times the child's age in years and add 65. Current calculation for the MAP for the 5th percentile at the 50th height percentile is to multiply 1.5 times age in years and add 40. To calculate MAP for the 50th percentile at the 50th height percentile, multiply 1.5 times the age in years and add 55 (Haque & Zaritsky, 2007).

Currently blood pressure percentiles are based on the database which is supplied by the NHPEP Working Group on High Blood Pressure in Children and Adolescents to the U.S. Department of Health. The data consists of readings taken from 63,227 children seen at 83,091 visits to physicians over the course of 11 studies. The estimated 50th, 90th, 95th, and 99th percentiles of blood pressure they provide are given by sex, year of age (1-17 years), and height percentile (5th, 10th, 25th, 50th, 75th, 90th, and 95th) for both systolic and diastolic blood pressure based on Karotkoff 5 sounds (Rosner, Cook, Portman, Caniels, & Falkner, 2008).

Kaelber (2007) indicated that children with hypertension and prehypertension are significantly underdiagnosed. Kaelber stated reasoning for this as the unwieldy tables presented by the U.S. Department of Health and Human Services in the blood pressure tables presented in the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents which include 476 blood pressure values for interpretation (Schuman, 2009).

Kaelber and his colleagues have modified the number of threshold values to 64, using simplified abnormal systolic and diastolic blood pressure values broken down by gender and ages 3-18. These abridged values are an attempt to simplify the identification of abnormal blood pressure values in a variety of care and screening settings to ensure efficiency and quality of care. The study leading to the revised values was named one of the top 10 breakthroughs in cardiovascular and stroke medicine for 2007 by the American Heart Association and earned 2008 Health Breakthrough Award from Ladies' Home Journal (Schuman, 2009).

Table 2 Blood pressure values requiring further evaluation, according to age and gender

	Male Blood Pressure nnHg		Female Blood Pressure mmHg	Female Blood Pressure mmHg
Ages	**Systolic**	**Diastolic**	**Systolic**	**Diastolic**
3	100	59	100	61
4	102	62	101	64
5	104	65	103	66
6	105	68	104	68
7	106	70	106	69
8	107	71	108	71
9	109	72	110	72
10	111	73	112	73
11	113	74	114	74
12	115	74	116	75
13	117	75	117	76
14	120	75	119	77
15	120	76	120	78
16	120	78	120	78
17	120	80	120	78
18	120	80	120	80

The simplified blood pressure table created by Kaelber and colleagues created to screen children for hypertension or prehypertension works on the assumption that all children and adolescents are at the 5th percentile for height (Schuman, 2009). This creates a potential limitation for children who are above the 5th percentile in height with normal blood pressure, to be misdiagnosed. The researchers justify the simplified chart in the knowledge that blood pressure measurement in and of themselves are imprecise with variables such as time of day when the reading is taken, the type of cuff used being either manual or automatic, the reading being taken in the office or an ambulatory setting, and who is doing the manual measurement (Schuman, 2009). Kaelber noted that the variations in the precision of the measurements are expected to vary between 6 to 9 mmHg for systolic and 3 to 5 mmHg for diastolic readings, which are equivalent to the variations attributed to the height differentiation (Schuman, 2009).

As awareness of the risks of childhood hypertension increase, and care providers consistently and properly measure childhood blood pressure, it can be expected that more children will be diagnosed with elevated blood pressures than previously recorded (Flynn, 2003).

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