# THE RELATIONSHIP BETWEEN HIGH SODIUM LEVELS IN MUNICIPALLY SOFTENED DRINKING WATER AND ELEVATED BLOOD PRESSURES

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ABSTRACT

A recent study in Massachusetts found that a group of high school sophomores exposed to 107 mg/l sodium in their drinking water had significantly higher blood pressures than a control group exposed to a lower level of sodium (8 mg/l). The present study was undertaken in Illinois to determine if these findings could be repeated with a group of high school juniors and seniors from two communities, LaGrange and Westchester, located in the Chicago metropolitan area. The concentration of sodium in LaGrange's municipal drinking water is 405 mg/l as compared to 4 mg/l for Westchester. Of the 386 eligible students in LaGrange, 84% volunteered to have their blood pressures taken. In Westchester, 78% of the 401 eligible students volunteered.

Results of the survey indicated that male and female systolic blood pressures in the high-sodium community were not higher than those in the low-sodium community ($p > 0.05$). In contrast, the male and female diastolic blood pressures were significantly higher in the high-sodium community ($p < 0.05$). However, the increases in diastolic blood pressures were not as large as those observed in the Massachusetts study. The long-term significance of these findings is unknown. However, they do indicate a need for further follow-up study to determine if there is an association with the development of hypertension.

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INTRODUCTION

Primary hypertension is a major affliction of modern society, affecting 15 to 20% of the adult population of the U.S. and other industrialized nations.[1] More than 20% of all deaths are directly or indirectly related to hypertension.[2] The causes of primary hypertension are not known. Several risk factors have been postulated, including age, sex, stress, obesity, sodium intake, race, genetic predisposition, degree of acculturation, and water mineralization.[1,3] Sodium intake is considered to be among the most important of these risk factors.[1,3-5]

Experimental studies with rats have produced unequivocal evidence that excessive ingestion of sodium is a factor in the pathogenesis of hypertension. Of particular significance are data indicating that: (a) the youngest animals are those most susceptible to salt-induced hypertension; (b) even relatively brief periods of exposure to a high-sodium diet in early life can result in permanent hypertension; and (c) genetic factors predispose certain strains to the development of hypertension.[4,5]

Although sodium intake by U.S. adults averages about 4 grams per day[6] (the extremes vary from 1 to 12 grams per day[5]), the daily requirement is less than 0.2 g; this amount is supplied by a diet of natural, unsalted foods.[5] There are studies which indicate that sodium is an important factor in the development of hypertension in humans. For example, a linear dose-response relation can be obtained when average daily sodium chloride intake (ranging from 3-26 g/day) is plotted against the proportions of hypertensives (ranging from 0-40% of the total population) for various world population groups.[4,5] Also, there is strong clinical evidence that a well-controlled low-sodium diet can reduce human hypertension even if there is no weight reduction.[4,5] Hereditary predisposition combined with excessive salt consumption may be the common means by which essential hypertension develops in humans.[5]

This introduction briefly reviews the literature for the role of dietary salt consumption as a risk factor in the development of hypertension in animals and humans. For a more extensive bibliography and discussion of this subject matter see the publications of Calabrese and Tuthill[9,11] and the National Academy of Sciences Report Drinking Water and Health.[12]

Sodium intake is usually substantially greater from food than from water. The proportion of waterborne sodium in the total diet is a function of the degree of municipal and/or home water softening and whether the diet is sodium-restricted (<500 mg/day[4]) for medical reasons. Municipal or home water-softening may add several hundred mg sodium/day to the amount normally derived from food (about 4 g/day). About 1.3 million people in Illinois are served by water which is municipally softened by either the lime-soda ash or zeolite techniques.[7] The investigators do not have an estimate of the number of persons served by home-softened water in Illinois.

Despite the low level of waterborne sodium in the diet, a recent study found that a group of high school sophomores exposed to sodium concentrations of 107 mg/l in drinking water had significantly higher blood pressures than a control group exposed to a lower level of waterborne sodium (8 mg/l).[8-10] The present study was undertaken to determine if those findings could be replicated in LaGrange, Illinois, a community which has an even higher level of sodium in its drinking water, 405 mg/l.

## METHODOLOGY

### Selection of Test and Control Communities

This survey was designed to compare the blood pressures of high school juniors and seniors from two communities in the Chicago metropolitan area that are separated by a distance of three miles (LaGrange and Westchester, Illinois). These communities were chosen because they have similar demographic and socioeconomic characteristics (Table 1). However the drinking water in LaGrange has a sodium concentration considerably higher than that of the drinking water in Westchester.

LaGrange has been softening its drinking water since 1938 by the standard techniques using lime-soda ash, zeolite, and/or continuous ion exchange.[14] These softening processes have caused the sodium concentrations to vary between 300 and 700 mg/l with a mean concentration (averaged for the years 1972-1978) of 405 mg/l.[15] This mean concentration was confirmed during the study period by the use of atomic absorption analysis of water samples. In contrast to LaGrange's very hard groundwater supply, Westchester's drinking water comes from Chicago (Lake Michigan source) which has a consistently low sodium concentration of about 4 mg/l.[15]

Selection of Study Populations

School board officials at Lyons Township High School, North Campus in LaGrange, and Proviso West High School in Hillside, Illinois were contacted to obtain approval for the study and listings of eligible junior and senior students. Juniors and seniors in Westchester attend Proviso West High School. Both Westchester and Hillside are supplied by drinking water from Chicago.

For the purposes of this study, eligible students were defined as those white, male or female, juniors or seniors living in LaGrange or Westchester who did not consume bottled water or water from the tap that had been treated to remove sodium (Appendix A). Also, four Westchester students residing in homes with water softeners were excluded from the data analysis because they might be consuming water with elevated sodium. The 42 LaGrange students with home water softeners were not excluded from the data analysis because additional home softening will result in only a slightly larger difference (less than

Table 1: Demographic and Socioeconomic Status Characteristics of LaGrange and Westchester, Illinois[13]

| Characteristic | LaGrange | Westchester |
|---|---|---|
| 1970 Population | 17,814 | 20,033 |
| % Population Change 1960-70 | +16.5 | +10.7 |
| Median Family Income | $16,552 | $15,812 |
| Median School Years Completed for Persons Over 25 | 13.3 | 12.4 |
| % Population Less than 18 Years of Age | 35.3 | 32.1 |
| % White | 97.2 | 99.8 |
| % Black | 2.5 | 0.1 |
| Household Size | 3.29 | 3.41 |
| Number of Dwelling Units | 5,194 | 5,890 |
| Number Employed, 16 Years Old or Older | 7,232 | 8,957 |
| a. % Professional-Manager | 37.9 | 31.9 |
| b. % Clerical-Sales | 35.6 | 34.7 |
| c. % Craftsmen-Operatives | 15.0 | 24.8 |
| d. % Laborers-Farmers | 2.8 | 2.2 |
| e. % Service | 8.7 | 6.5 |

10%) in sodium concentration in the drinking water between test and control communities. Furthermore, eligible siblings were randomly removed so that only one junior or senior would be represented per family. As a consequence, familial effects on the blood pressure data were removed. There were 386 eligible students in LaGrange and 401 eligible students in Westchester. Due to the excellent cooperation of school personnel and parents and to an incentive of five dollars to participate in this study, approximately 84% of the eligible students from LaGrange (325) and 78% of the eligible students from Westchester (313) volunteered.

Collection of Blood Pressure Data

Each student was given a short questionnaire designed to collect data on variables which affect blood pressure, e.g. duration of residence in community, height and weight, intake of salty food, and smoking (Appendix B). (Due to budgetary constraints, comprehensive information on dietary habits [e.g. type and amount of fluid and solid food intake] was not obtained. However, a small subsample of students was evaluated for their intake of tap water and excretion of urinary sodium.) All students completed the short questionnaire, and after their heights and weights were recorded, they were told to report to one of three stations to have blood pressures taken by a nurse or trained volunteer. All blood pressures were taken with a mercury sphygmomanometer on the left arm of the seated student. The student's arm rested on a table and was at heart level with palm up. The student assumed a relaxed, comfortable position, sitting quietly with legs uncrossed.

With the use of a stethoscope, blood pressures were recorded using the first and fifth Korotkoff sounds as the bases for the systolic and diastolic blood pressures, respectively. The rate of descent of the pressure was kept at the recommended 2-3 mmHg per second.[16] Each student had three consecutive blood pressures and a single pulse rate taken during a five minute period. Students with blood pressures above normal (>140 mmHg systolic and/or >90 mmHg diastolic) were advised to consult their physicians. For data analysis purposes the second and third blood pressure readings were averaged to obtain the representative value for each student. The first blood pressure was excluded from the data analysis because there are indications that the initial blood pressure is somewhat higher than subsequent readings.[16]

Blood pressure measurements were taken by a staff consisting of registered nurses from the LaGrange Visiting Nurses Association and trained volunteers from the Chicago Heart Association. The same personnel and mercury sphygmomanometers were utilized to carry out the screening in each school. The screening was carried out on January 8-10, 1980, in LaGrange, and on February 5-7, 1980, in Westchester.

Urinalysis and Liquid Intake Study

At the completion of the blood pressure survey, students were offered ten dollars as an incentive to attract volunteers into the urinalysis and liquid intake study. One purpose of this study was to measure and compare urinary sodium excretion between test and control communities as an index of overall (food and water) sodium intake. Another purpose was to determine the volume of tap water consumed per student to confirm that LaGrange students were actually exposed to the high-sodium municipal water. Students were asked to collect seven overnight urine samples and complete a liquid intake diary (Appendix C) for each of those seven days. Overnight urine samples were defined as all urine voided during the night and the first urine voided upon awakening in the morning. Urine samples were obtained from 41 LaGrange and 39 Westchester students. Urinary sodium ion concentrations were determined by flame emission spectrophotometry using a Perkin-Elmer 5000 Atomic Absorption Spectrophotometer.[17] Participants were instructed to complete the liquid intake diary by estimating the amount of tap water and tap-water-based fluids they consumed. Graduated drinking cups were provided to the participants to assist them with their estimations.

Statistical Analysis

Comparison of the systolic and diastolic blood pressures from the two study groups was done by analysis of covariance using the general linear model (GLM) procedure of the Statistical Analysis System,[18] with separate analyses for males and females. Analysis of covariance allows comparison of group means after adjustment for possible confounding variables (covariates). The covariates considered in the present analysis were the salty food index (FOOD), daily cigarette use (CIG), Quetelet index (QUET), and months of residence in the community (RES). Adjustment was not necessary for the covariates listed in Table 1 because of the similarity in these variables between the two communities studied. Only those with complete covariate and blood pressure data were included in this analysis (309 and 303 students from LaGrange and Westchester, respectively).

The purpose of computing the food index was to determine if there was a difference between the two communities regarding intake of salty foods. This index was calculated by assigning values to the 14 categories of foods listed in the questionnaire (Appendix B) as follows: if the boxes never or less than once a week were checked, a value of one was assigned; a value of two was assigned if the box 1-2 times per week was checked; and a value of three was assigned if the boxes 3-6 times per week or 7 or more times per week were checked. No index was computed if consumption was not specified for at least thirteen of the fourteen categories. For those who did not answer one of the food questions, the modal value for the same town/sex group was assigned.

The food index was then computed in the normal way. Therefore, each individual had a food index in the interval 14-42.

Daily cigarette use (CIG) was coded as a zero if the individual did not smoke, a 1 (one) if less than one-half pack per day was smoked, a 2 (two) if one-half to one pack per day was smoked, and a 3 (three) if more than one pack a day was smoked.

The Quetelet index (QUET)[19] calculated as $(\text{weight}/\text{height}^2) \times 100$ was utilized to describe the obesity of the subjects. Weight was measured in kilograms, and height in centimeters.

The length of residence in the community (RES) was another important confounder to consider because, if sodium in drinking water affects blood pressure, a greater blood pressure elevation may be shown in those individuals consuming the high-sodium water for a longer period of time.

The urinary sodium excretion and water intake data were analyzed using a weighted two-way analysis of variance. Only those individuals who submitted at least five urine samples were included in the statistical analysis of urinary sodium levels. Participants were required to provide at least three days of water intake diaries to be included in the analysis of water consumption. Individual mean urinary sodium and water intake values were weighted by the inverse of their respective variances.

RESULTS

Blood Pressure Survey

There were 172 males and 137 females from LaGrange and 142 males and 161 females from Westchester whose blood pressures were used in data analysis. The mean average systolic and diastolic blood pressures for LaGrange and Westchester males and females are listed in Table 2. These results indicated that

Table 2: Mean Average Systolic and Diastolic Blood Pressures (mmHg)[a] of High School Students from LaGrange and Westchester, Illinois

| | LaGrange (High-Sodium Community) | | | Westchester (Low-Sodium Community) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N[b] | Mean[a] | SEM[c] | N | Mean | SEM | Difference of Means | t | Degrees of Freedom | p-Value[d] |
| Males | 172 | | | 142 | | | | | | |
| Systolic | | 115.59 | 0.79 | | 118.81 | 0.78 | -3.22 | -2.85 | 312 | 0.998 |
| Diastolic | | 70.11 | 0.65 | | 68.29 | 0.82 | 1.82 | 1.76 | 312 | 0.040 |
| Females | 137 | | | 161 | | | | | | |
| Systolic | | 106.89 | 0.74 | | 105.65 | 0.76 | 1.24 | 1.16 | 296 | 0.123 |
| Diastolic | | 67.96 | 0.61 | | 66.02 | 0.65 | 1.94 | 2.15 | 296 | 0.016 |
| | 309 | | | 303 | | | | | | |

a. Based on average of second and third blood pressure measurements for each individual.

b. Sample size.

c. Standard error of the mean.

d. Based on one-tailed t-test (hypothesis: blood pressures in LaGrange > blood pressures in Westchester).

male and female systolic blood pressures in the high-sodium community were not higher, at the 0.05 level of significance, than those in the low-sodium community. In contrast, the male and female diastolic blood pressures were significantly higher (P=0.040 for males and P=0.016 for females) in the high-sodium community. The significant differences were a 1.8 mmHg elevation in mean average diastolic blood pressure among males and a 1.9 mmHg elevation in mean average diastolic blood pressure among females in the high-sodium community.

The analysis of covariance of the average systolic and diastolic blood pressures (SBP, DBP) was initially computed utilizing all four covariates (CIG, QUET, RES, FOOD). Standard backward elimination procedures were employed to develop simplified models with only the most important covariates being included in the model (partial "F-to-remain" tests yielding p-values $\leq$ 0.10). For purposes of implementing the GLM procedures, the community variable (TOWN) was a dummy variable, with LaGrange coded as "1" and Westchester coded as "zero." The final models and their associated $R^2$ values are:

MALES

$$SBP = 97.51 - 3.71\ TOWN + 9.48\ QUET \qquad (R^2 = 0.119)$$

$$DBP = 58.46 + 1.60\ TOWN + 4.37\ QUET \qquad (R^2 = 0.034)$$

FEMALES

$$SBP = 92.39 + 1.60\ TOWN + 6.15\ QUET \qquad (R^2 = 0.060)$$

$$DBP = 58.78 + 2.02\ TOWN + 1.06\ CIG + 3.08\ QUET \qquad (R^2 = 0.044)$$

Finally, although the food and residence indices were considered as potential covariates in this study, they were found to be statistically unimportant for explaining the variability of blood pressure in the two communities.

The results of the one-way analysis of covariance, which adjusted for these confounding variables, are tabulated in Table 3. In comparing the

Table 3: Adjusted Mean Average Systolic and Diastolic Blood Pressures (mmHg)[a] of High School Students from LaGrange and Westchester, Illinois

| | LaGrange (High-Sodium Community) | | | Westchester (Low-Sodium Community) | | | | |
|---|---|---|---|---|---|---|---|---|
| | N[b] | Adjusted Mean[c] | SEM[d] | N | Adjusted Mean | SEM | Difference of Means | p-Value[e] |
| Males | 172 | | | 142 | | | | |
| Systolic | | 115.37 | 0.72 | | 119.08 | 0.80 | -3.71 | 0.999 |
| Diastolic | | 70.01 | 0.69 | | 68.41 | 0.76 | 1.60 | 0.061 |
| Females | 137 | | | 161 | | | | |
| Systolic | | 106.77 | 0.77 | | 105.75 | 0.71 | 1.02 | 0.164 |
| Diastolic | | 68.00 | 0.66 | | 65.98 | 0.61 | 2.02 | 0.013 |
| | 309 | | | 303 | | | | |

a. Based on average of second and third blood pressure measurements for each individual.

b. Sample size.

c. Adjusted for one or two of the covariates, Cigarettes and Quetelet Index {(weight/height$^2$) X 100}, using the models described in the text.

d. Standard error of the mean.

e. Based on one-tailed t-test (hypothesis: blood pressures in LaGrange > blood pressures in Westchester.

differences between the adjusted means in Table 3 and the unadjusted means in Table 2, it is noted that adjustments had little effect on the mean average blood pressures.

Urinalysis and Liquid Intake Study

The mean urinary sodium excretions for males and females from the high-sodium community were not significantly different ($p > 0.05$) when compared to the male and female sodium excretions from the low-sodium community (Table 4). Adjustment for the amount of water ingested did not alter the findings. In addition, the mean water intake values for males and females were not significantly different ($p > 0.05$) in the two communities studied (Table 5).

## DISCUSSION

The major objective of this study was to determine if the findings of the Massachusetts study[9] could be replicated in Illinois. As noted in the comparison of these two studies in Table 6, the Illinois study did not completely replicate the previous findings. Also, the unadjusted means are used in comparing the two studies because adjustment for the covariates did not change the strength or direction of the findings appreciably. The Massachusetts study found: (1) elevated male and female systolic and diastolic blood pressures in the high-sodium community when compared to the low-sodium community, and (2) 2.7-5.1 mmHg increases in the systolic and diastolic blood pressures in the high-sodium community. In contrast, the Illinois study did not find elevated male and female systolic blood pressures in the high-sodium community. The male and female diastolic blood pressures were elevated in the high-sodium community. These diastolic blood pressure results are in qualitative agreement with the Massachusetts study. However, the increases in diastolic blood pressures (approximately 2 mmHg for

Table 4: Mean Overnight[a] Urinary Sodium Excretions in Milligrams (mg) for High School Students from LaGrange and Westchester, Illinois

| | LaGrange (High-Sodium Community) | | | Westchester (Low-Sodium Community) | | | |
|---|---|---|---|---|---|---|---|
| | Sample Size | Sodium Mean | Sodium SEM[b] | Sample Size | Sodium Mean | Sodium SEM | p-Value[c] |
| Males | 21 | 586.02 | 75.64 | 23 | 721.66 | 73.34 | 0.925 |
| Females | 20 | 747.40 | 68.05 | 16 | 747.63 | 62.30 | 0.500 |

a. Overnight urine samples were defined as all urine voided during the night and the first urine voided upon awakening in the morning.

b. Standard error of the mean.

c. Based on one-tailed t-test (hypothesis: sodium excretion in LaGrange > sodium excretion in Westchester).

Table 5: Mean Daily Tap Water Intake in Milliliters (ml) and Mean Daily Milligrams (mg) Sodium Ingested from the Tap Water[a] for High School Students from LaGrange and Westchester, Illinois

| | LaGrange (High-Sodium Community) | | | | Westchester (Low-Sodium Community) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sample Size | Water Intake Mean | Water Intake SEM[b] | Ingested Sodium Mean | Sample Size | Water Intake Mean | Water Intake SEM | Ingested Sodium Mean | p-Value[c] |
| Males | 19 | 552 | 62 | 223.56 | 22 | 428 | 52 | 1.71 | 0.066 |
| Females | 19 | 327 | 39 | 132.45 | 16 | 277 | 53 | 1.11 | 0.236 |

a. Based on a mean of 405 mg/l sodium in LaGrange's tap water and 4 mg/l sodium in Westchester's tap water.

b. Standard error of the mean.

c. Based on one-tailed t-test (hypothesis: water intake in LaGrange > water intake in Westchester).

Table 6: Comparison of Mean Average Blood Pressures (mmHg) Between the Massachusetts[9] and Illinois Studies[a]

| | Massachusetts Study Communities | | | | | Illinois Study Communities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High-Sodium | | Low-Sodium | | | High-Sodium | | Low-Sodium | | |
| | N[b] | Mean[c] | N | Mean | p-Value[d] | N | Mean[e] | N | Mean | p-Value |
| MALES | 140 | | 126 | | | 172 | | 142 | | |
| Systolic | | 123.11 | | 119.54 | < 0.008 | | 115.59 | | 118.81 | 0.998 |
| Diastolic | | 65.17 | | 62.48 | < 0.012 | | 70.11 | | 68.29 | 0.040 |
| FEMALES | 160 | | 180 | | | 137 | | 161 | | |
| Systolic | | 113.49 | | 108.38 | < 0.001 | | 106.89 | | 105.65 | 0.123 |
| Diastolic | | 67.80 | | 62.69 | < 0.001 | | 67.96 | | 66.02 | 0.016 |
| | 300 | | 306 | | | 309 | | 303 | | |

a. The unadjusted means are used in comparing the two studies because adjustment for the covariates did not change the strength or direction of the findings appreciably.

b. Sample size.

c. Based on an average of first, second, and third blood pressure measurements for each individual.

d. Based on one-tailed t-test (hypothesis: blood pressures in high-sodium community > blood pressures in low-sodium community).

e. Based on an average of second and third blood pressure measurements for each individual.

males and females) were not as large as those observed in the Massachusetts study (2.7 and 5.1 mmHg for males and females, respectively).

There were several differences in study design. First, the Massachusetts study reported systolic and diastolic blood pressure data based on an average of three readings per individual that were taken by three different nurses. The blood pressure data in this study were reported as an average of the second and third readings taken by the same nurse. The first blood pressure reading was excluded from the data analysis because other studies have indicated that the initial blood pressure reading is somewhat higher than subsequent readings.[16]

Second, the Massachusetts study obtained self-reported height and weight values, while the heights and weights of each student were measured in the Illinois study.

Although a comprehensive assessment of the relationship of diet to blood pressure was not undertaken in either study, the Illinois study assessed overall (food plus water) dietary sodium intake by measuring overnight sodium excretion, whereas the Massachusetts study used a questionnaire. The link between overall dietary sodium intake and urinary excretion is excellent.[20] (Except for usually small losses in sweat, the loss of sodium from the body occurs in the urine, so the rate of urinary sodium excretion is approximately equal to the rate of salt ingestion. The loss of sodium must equal the dietary intake for the body to remain in sodium balance.) From Table 4, it can be seen that no significant difference in urinary sodium was found between the two groups of students. This implies that there probably was no difference in overall dietary sodium intake between the communities. As a consequence, the additional sodium consumed from the high-sodium community's drinking water was not discernible in the students' urine because sodium from food sources cancelled out the differences in sodium from the two drinking water supplies.

Two final differences between the two studies were the following: 1) the Massachusetts study obtained socioeconomic data by use of a questionnaire, while the Illinois study relied totally on the Surburban Fact Book 1973[13] for this information; 2) the Massachusetts study adjusted their data for 18 co-variates, while the Illinois study made adjustments for four covariates. It is not clear how the 18 covariates were measured in the Massachusetts study. As mentioned previously, the Illinois study adjusted for only those covariates where differences were found important in explaining the variability of the blood pressures. Finally, the adjustments made did not change the strength or direction of the findings appreciably in either study.

It is of interest to compare the blood pressures found in this study to values from a larger population base. The percent of males and females in both the high- and low-sodium communities that were 16 or 17 years of age ranged from 88-93%. Their blood pressures were compared to the 1971-1974 National Center for Health Statistics (NCHS) blood pressure data obtained in the HANES study.[16] As seen in Table 7, the HANES blood pressure data is generally higher than the male and female blood pressure data for either the high- or low-sodium communities. It was explained in the HANES report that their single measurement of an individual's blood pressure can be considered only a rough estimate of the "true" blood pressure because the initial blood pressure is generally somewhat higher than subsequent readings.[16]

## SUMMARY AND CONCLUSIONS

Studies which indicate that sodium is an important factor in the development of hypertension in humans have primarily investigated sodium intake from food sources and have ignored water as an additional source of sodium. A study

Table 7: Comparison of Blood Pressures Between Illinois Study Groups and the HANES Survey

| | LaGrange (High-Sodium Community) | | | Westchester (Low-Sodium Community) | | | HANES Data[16] | | |
|---|---|---|---|---|---|---|---|---|---|
| | N[a] | Mean[b] | SEM[c] | N | Mean | SEM | N | Mean | SEM |
| MALES | | | | | | | | | |
| Systolic | | | | | | | | | |
| 16 years old | 66 | 116.3 | 1.44 | 63 | 119.7 | 1.24 | 2,059 | 119.1 | 1.44 |
| 17 years old | 85 | 116.7 | 1.29 | 65 | 121.3 | 1.21 | 2,137 | 119.5 | 1.43 |
| Diastolic | | | | | | | | | |
| 16 years old | 66 | 67.8 | 1.37 | 63 | 66.5 | 1.19 | 2,059 | 72.8 | 0.73 |
| 17 years old | 85 | 68.9 | 0.96 | 65 | 67.9 | 1.51 | 2,137 | 73.7 | 1.08 |
| FEMALES | | | | | | | | | |
| Systolic | | | | | | | | | |
| 16 years old | 67 | 108.1 | 1.32 | 71 | 109.6 | 1.16 | 2,050 | 113.6 | 1.19 |
| 17 years old | 60 | 108.7 | 1.15 | 78 | 105.9 | 1.18 | 1,710 | 112.2 | 1.51 |
| Diastolic | | | | | | | | | |
| 16 years old | 66 | 67.6 | 1.00 | 71 | 67.2 | 0.94 | 2,050 | 69.4 | 0.95 |
| 17 years old | 59 | 66.7 | 1.05 | 78 | 64.0 | 1.18 | 1,710 | 71.2 | 1.20 |

a. Sample size.
b. Based on a single blood pressure measurement for each individual.
c. Standard error of the mean.

conducted in Massachusetts[9] indicated that high school sophomores exposed to 107 mg/l sodium in their drinking water had significantly higher blood pressures than a control group exposed to 8 mg/l sodium. The results of the present study did not completely corroborate those findings either in terms of the strength of association or the consistency in the direction of blood pressure differences. Healthy junior and senior high school students exposed to 405 mg/l of sodium in their drinking water did not have increased systolic blood pressures when compared to a similar control group exposed to 4 mg/l sodium. However, the diastolic blood pressures of the males and females in the high-sodium group were elevated about 2 mmHg; whereas, the Massachusetts study found an elevation of 2.7 and 5.1 mmHg for males and females, respectively.

Since the long-term significance of the Illinois study is unknown, it is recommended that a prospective epidemiological study be conducted to determine absolutely whether elevated sodium levels in drinking water affects blood pressures.

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## APPENDIX A

Bottled Water Survey
Of High School Students Who Participated In The
University of Illinois Blood Pressure Survey In
January/February 1980

NAME OF STUDENT ______________________________

In order to complete our study, we would like to obtain the following additional information from you.

Questions

1. Does your family substitute any other water for LaGrange tap water? "Substitute" does not mean refrigerated tap water!

   Yes ☐ No ☐ (Stop if "No")

2. What type of water is substituted for LaGrange tap water?

   Commercial bottled water (Hinckley Schmitt, grocery store, distilled, etc.) ☐

   Chicago ☐

   LaGrange Park ☐

   Other (specify) ______________ ☐

3. Do you drink any of the substitute water? Include beverages (orange juice, lemonade, soup, etc.) made with the substitute water.

   Yes ☐ No ☐ (Stop if "No")

4. How long have you consumed the substitute water?

   Years ________ If less than one year, how many months ________

5. Do you drink any LaGrange tap water at home, school, etc.?

   Yes ☐ No ☐ (Stop if "No")

   Include beverages (orange juice, lemonade, soup, etc.) made with tap water.

6. Which do you drink more of?

   LaGrange tap water ☐

   Substitute water ☐

## APPENDIX B

## BLOOD PRESSURE SURVEY

I. The following questions are about you and your family.

1a. Do you currently smoke cigarettes?

Yes ☐ No ☐ → skip to 2

b. How many cigarettes do you smoke a day? (check one)

more than 1 pack ☐ between 1/2 and 1 pack ☐

less than 1/2 pack ☐

2a. Do you have a home water softener? (check one)

Yes ☐ No ☐ Don't know ☐ → skip to 3

b. How long have you had the softener?

________________ Years Don't know ☐

c. Is the softener on your: (check one)

hot water only ☐ "open tap" ☐

cold water only ☐ Don't know ☐

hot and cold ☐

3a. What is your address? ______________________________

Street City

b. How long have you lived at this address?

________________ Years ______________ Months

4. When were you born? ______________________________

Month Day Year

5. What is your full name? ______________________________

Last First Middle

II. The following questions are about your eating and drinking habits.

6. Please check one box to indicate how often you have eaten each of the following foods in the last month.

| | never | less than once a week | 1-2 times per week | 3-6 times per week | 7 or more times per week |
|---|---|---|---|---|---|
| bacon | | | | | |
| other smoked meats (example: salami, smoked fish, sausages) | | | | | |
| canned foods containing meat (examples: chili, spaghetti, raviolo, stew) | | | | | |
| canned fish (examples: tuna, salmon, sardines) | | | | | |
| canned vegetables of any kind | | | | | |
| hard cheeses (examples: cheddar, swiss) | | | | | |
| cottage cheese | | | | | |
| jello | | | | | |
| salted nuts | | | | | |
| snack crackers | | | | | |
| snack foods such as cheetos, fritos, potato chips, cheese curls, etc. | | | | | |
| pickles | | | | | |
| peanut butter | | | | | |
| french fries | | | | | |

FOR OFFICIAL USE ONLY

Data Sheet

Date_______________ time(nearest 1/2 hour)_______________

Height:__________ ft__________ in

Weight__________ lbs

Pulse (number of beats in 30 seconds)_________ x2 = _______________ beats/min

Blood pressure

| | Systolic | | Diastolic |
|---|---|---|---|
| reading 1 | ☐☐☐ | | ☐☐☐ |
| reading 2 | ☐☐☐ | | ☐☐☐ |
| reading 3 | ☐☐☐ | | ☐☐☐ |
| | ________ | sum | ________ |
| average of readings 2 and 3 | ________ | | ________ |

APPENDIX C

LIQUID INTAKE DIARY

We would like you to record all that you drink for the next 7 days. Please keep this diary with you and place a check in the appropriate box whenever you drink during the day. An example is provided at the back of this booklet. A list provided at the top of each page will give you an idea of approximate volumes for containers. If you are not able to find the container size you used, pour the liquid to be drunk into the graduated cup provided. This booklet contains 9 sheets (2 extra) for data collection. Please fill these in one day at a time and return them to the box located in the Nurses' office the following morning at the time of drop-off of your urine specimen. For example:

> Monday (11/5) diary sheet would be turned in Tuesday morning (11/6), along with Tuesday morning's urine specimen.

EXAMPLE:
Date: Monday, 11/5

1 cup milk - breakfast (see first check in column 3, row 1)
Drink of water out of fountain - school (see check in column 1, row 2c)
1 can soda - lunch (see check in column 4, row 3)
1 large glass water (tap) studying (see check in column 3, row 2a)
1 cup milk - bedtime (see second check column 3, row 1
1 can Kayo chocolate beverage (check in column 4, row 4)

Single serving milk carton - 8 oz or 240 ml
White Styrofoam hot cup 7 oz or 210 ml
Small "Dixie" paper cup - 4 oz or 120 ml
Soup bowl - 8 oz or 240 ml
Soda can - 12 oz or 360 ml
Large glass 10 oz or 300 ml

DATE: Monday, 11/5

| Type of Liquid | less than 1/2 cup | 1/2 cup 4-7 oz 120-210 ml | 1 cup 8-11 oz 240-340 ml | 1 1/2 cup 12-15 oz 360-450 ml | 2 cups 16-23 oz 480-700 ml | 3 or more cups |
|---|---|---|---|---|---|---|
| 1. Milk | | | ✓✓ | | | |
| 2. Water a) tap | | | ✓ | | | |
| b) bottled | | | | | | |
| c) drinking fountain | ✓ | | | | | |
| 3. Soda Pop | | | | ✓ | | |
| 4. Other (specify): Kayo | | | | ✓ | | |

If you are not able to find the container size you used, try to estimate its volume from this list.

Single serving milk carton - 8 oz or 240 ml
White Styrofoam hot cup - 7 oz or 210 ml
Juice glass - 5 oz or 150 ml
Small "Dixie" paper cup - 4 oz or 120 ml
Soup bowl - 8 oz or 240 ml
Soda can - 12 oz or 360 ml
Vending machine cup 6 oz or 180 ml
Large glass - 10 oz or 300 ml

DATE (day of week/mo./date):

| Type of Liquid | less than 1/2 cup | 1/2 cup 4-7 oz 120-210 ml | 1 cup 8-11 oz 240-340 ml | 1 1/2 cups 12-15 oz 360-450 ml | 2 cups 16-23 oz 480-700 ml | 3 or more cups |
|---|---|---|---|---|---|---|
| 1. Milk | | | | | | |
| 2. Water a) tap | | | | | | |
| b) bottled | | | | | | |
| c) drinking fountain | | | | | | |
| 3. Soda Pop | | | | | | |
| 4. Juice a) frozen concentrate | | | | | | |
| b) ready-made | | | | | | |
| 5. Hot beverages (coffee, tea, hot chocolate, etc.) | | | | | | |
| 6. Powdered mixes (lemonade, iced tea, Kool-aid, etc.) | | | | | | |
| 7. Soup a) instant (powder) or condensed (canned) | | | | | | |
| b) homemade stock | | | | | | |
| 8. Jello | | | | | | |
| 9. other (specify) | | | | | | |
| | | | | | | |
| | | | | | | |