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Excess Consumption of Sugar-Sweetened Beverages and Sodium in Children and Adolescents

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Keywords: Sugar Beverages, Sodium, Children, Adolescents, Health

ABSTRACT:

Consumption of sugar-sweetened beverages and sodium-rich foods are increasingly becoming commonplace in the diets of American children and adolescents. Aside from the well-characterized health outcomes such as obesity and diabetes, these foods pose direct risks in terms of increasing the likelihood of dental caries, elevated uric acid, and hypertension in children and adolescents as well as displacing foods necessary to healthy growth and development. The following two-part review examines consumption of sweetened beverages and sodium-rich foods in relationship to associations with immediate and long-term health effects, describes population sub-groups that are especially susceptible, and proposes policy and individual-level prevention strategies.

INTRODUCTION:

Changes in dietary consumption patterns can have immediate effects as well as longer-term consequences. The American diet and individual consumption patterns have dramatically changed over the past two decades, and these changes are suggested to be responsible for prevalence increases in diabetes, metabolic syndrome, heart disease, and dental caries.[1-6] Recent evidence from three longitudinal cohort studies demonstrates the impact of increased sugar sweetened beverages as well as sodium rich potato chips and processed meat consumption on longer-term health outcomes.[7]

The following review will discuss the influence of increased consumption of sugar-sweetened beverages and sodium in the diets of American children and adolescents in relationship to immediate health effects as well as longer-term consequences.

LITERATURE SEARCH STRATEGY:

We split the search strategy into two parts and used the following terms: 1) ‘sugar-sweetened beverages’, ‘soda’, ‘adolescents’, ‘children’, ‘health’; and 2) ‘sodium’, ‘adolescents’, ‘salt’, ‘children’, ‘health’. We restricted the search to English and humans and primarily focused our article collection on non-obesity related health outcomes. We accessed PUBMED, CINHL, and Google Scholar. We utilized review papers to provide conceptual information and summarized evidence. We accessed primary literature from cross-sectional designs, population-based epidemiology studies, randomized clinical trials, and ecologic studies to construct our tables of evidence.

SUGAR-SWEETENED BEVERAGE CONSUMPTION:

American children and adolescents consume more discretionary calories than recommended. This is true for children of all ages, regardless of ethnicity and socioeconomic status.[8] Included among substances classified as discretionary calories are sugar-sweetened beverages [SSBs], and intake of these in particular has increased markedly over the last 30 years: in 2004, for example, 13% of a child’s daily caloric intake came from SSBs, accounting for 300 discretionary calories per day or nearly double the recommended amount.[8] This trend is concerning because regular consumption of SSBs, especially soda, increases risk for child and adolescent overweight and obesity, and longer-term risk for type II diabetes in adulthood.[5,9] But SSB consumption is associated with other, less appreciated health outcomes. Namely, in addition to replacement of critical nutrients in childhood nutrition, SSB intake is associated with dental caries,[10] increased uric acid, and elevated blood pressure (Table 1).[11]

SSBs replace nutrients believed to be critical to childhood development. Insufficient intake of essential nutrients in children and adolescents could have adverse effects on skeletal health, bone development, and statural growth.[12] As children grow up, their soda consumption is observed to increase progressively.[13] Studies show that consuming sodas is inversely related with milk intake.[13] This is concerning as milk positively associates with meeting recommended vitamins A, B_{12}, and calcium.[14] In addition to displacing milk intake, soda has been shown to negatively associate with meeting the daily-recommended vitamin A for all ages, vitamin C for ages 2-5, B_{12} for ages 6-11, and calcium for ages 2-11.[14] By drinking SSBs, children and adolescents reduce their milk consumption and ultimately diminish their intake of vital nutrients.

In addition to nutrient intake, SSB consumption poses a potential long-term risk of dental caries (Table 1). Data shows that children with dental caries drink significantly more soda than children without dental caries; in comparison, children with low or no soda intake experience a reduced number of dental caries.[15] Regardless of gender, race, socioeconomic status and education level, SSB consumption strongly correlates with experience of plaque and dental caries.[6] Soda intake also poses cumulative effects, as a child's age shows significant positive association with the number of dental caries.[10,15] To curb the collective effects of today's childhood drinking patters, children are urged to restrict their SSB intake to intermittent use.[15,16]

Children's oral health significantly impacts their wellbeing and quality of life. Children with early childhood caries [ECC] experience poorer physical, mental, and social functioning than caries-free children.[16] In addition, ECC affect school performance. In 1989, a staggering 117,000 hours of school were lost per 100,000 students because of dentist visits or oral problems.[17] Sadly, ECC affect far more than a child's wellbeing. Children, families, communities and the healthcare system at large are all impacted by ECC. Societal costs are vast and include missed school days, missed work, excessive use of over-the-counter medications, parental stress, reduced eating and sleeping, pain, misuse of the Emergency Department, medications, and hospital stays.[18] ECC remain the most common childhood disease in the U.S and surprisingly many Emergency Departments report dental pain as their top reason for pediatric admissions.[16,18] Although the impact of ECC remains low on an individual level, its effects are strong on a societal level.[17] By simply reducing the number of SSBs consumed, children and adolescents can potentially decrease their number of dental caries, and in turn improve their quality of life.[15,16]

Elevated SSB consumption also poses cardiovascular risks to children and adolescents including increased uric acid and blood pressure. Studies found that the more soda children consume, the higher their serum uric acid levels.[11] These findings are significant because in adolescents, serum uric acid levels correspond with cardiovascular risk factors including hypertension and metabolic syndrome.[11] Whereas regular soda intake impacts serum uric acid levels, diet soda consumption is inversely associated with serum uric acid levels.[19] Increased SSB consumption also impacts systolic blood pressure. Children who drink more than 36 ounces of SSBs per day experience a mean systolic blood pressure increase of 0.17 mmHg.[11] A 0.17 mmHg increase represents a blood pressure difference of 2 mmHg.[11] Thus, primary intervention strategies are critical because reducing systolic blood pressure by 2 mm Hg decreases the risk of ischemic heart disease by 7% and stroke mortality by 10%.[11] Regardless of weight drinking less SSBs benefits all young people in terms of promoting cardiovascular health.[11]

SSB consumption in children and adolescents remains a pressing problem in the U.S. Minimizing SSB intake does not have adverse effects on children's health; it can only decrease the risks of childhood obesity and health problems including poor nutrition, dental problems and cardiovascular risks.[8] Targeted primary prevention strategies including parental education and community outreach efforts focusing on limiting SSB availability can influence childhood drinking habits.[8,20,21] Further research is needed to fully understand the health risks of SSB consumption and to determine the most effective prevention strategies to overcome this growing problem.

SODIUM INTAKE AND HYPERTENSION IN AMERICAN CHILDREN AND ADOLESCENTS:

Hypertension in American children and adolescents is an important health issue. Prevalence is increasing and negative effects on immediate and long-term health outcomes are becoming more apparent (see Table 2). Childhood hypertension is an area of concern because the condition often persists into adulthood as shown by carotid intimal-medial thickening, left ventricular hypertrophy, and fibrotic plaque formation.[22] Additionally, an increase in blood pressure can lead to other significant health problems later in life, including diabetes mellitus, cerebrovascular complications, and renal disease.[22] Investigating possible causes of high blood pressure among the American youth, such as excessive dietary sodium intake, is critical to decreasing healthcare costs for the public and promoting a healthier population. Sodium consumption in both male and female adolescents has markedly increased over the past decade.[23] Although 2005 Dietary Guidelines for Americans recommend limiting sodium consumption to 2300 mg/day, National Health and Nutrition Examination Survey data show the rates of sodium consumption are 4266 mg/day and 2950 mg/day for 12-19 year old males and females, respectively.[23,24]

Adults who had hypertension as children usually seek medical care after a considerable amount of irreversible damage has been done to organs and the arterial system.[25] Therefore, preventing high blood pressure at adolescence is more feasible and beneficial to the individual and public than treating hypertension in adulthood. Prevention can be delivered by implementing low sodium diet plans, encouraging an active lifestyle, and educating children about the effects of sodium on blood pressure.[26] Each mmHg increase in blood pressure influences risk for stroke, ischemic attacks, and cardiovascular disease. Decreasing the amount of sodium in food and drinking water is an important step that ought to be considered for the American youth.[27,28] Because children often have difficulties accepting changes in their diet, unique approaches are needed to increase compliance.[22]

Educating American children at a young age is an important intervention for the general population because children normally do not understand health implications.[29] Children's minds are still very malleable, and there is an opportunity to influence their mindset in a positive way to initiate healthy eating and exercise habits.[30] Children are influenced by the lifestyle habits of adults around them as they grow up. Therefore, it is important that adults become knowledgeable about health implications of excessive dietary sodium.[29]

Sub-groups of children and adolescents may be more susceptible to developing hypertension. Higher salt threshold leads to decreases in the ability to detect salt through taste, causing children and adolescents who are sodium sensitive to be especially vulnerable to sodium related hypertension.[31] Fortunately, sodium sensitive individuals tend to have greater reductions in blood pressure with reduced salt intake, so dietary changes could lead to substantial improvements in health.[30] According to many studies, children born with low birth weights also tend to develop hypertension more frequently than normal birth weight individuals.[32] Another vulnerable group is overweight children and adolescents. The prevalence of high blood pressure in obese children has increased to 30% in the American population.[22] Though obese adolescents tend to have blood pressures that are sensitive to salt intake, weight loss can reverse this sensitivity.[33] Low birth weight children, obese children, and salt sensitive children and adolescents are at increased risk for hypertension. Therefore, additional resources for development and evaluation of effective prevention and treatment methods are especially needed for these vulnerable populations.

Implementation of stricter guidelines for sodium content in food and water[34] may be necessary, particularly in processed and restaurant foods, the sources with the highest sodium concentrations.[35] Along with policy guidelines, individual-level change is critical for risk reduction. A well-known dietary plan that individuals could adopt is the DASH (Dietary Approaches to Stop Hypertention)-diet, which consists of increased fruit and vegetable consumption and decreased levels of saturated and total fat. Because fruit and vegetables naturally contain less sodium, the DASH-diet can help decrease children's sodium intake and subsequently lower systolic blood pressure by 8 to 14 mmHg.[22,30] The U.S. government could provide educational materials for parents that provide information about how reductions in sodium can decrease both systolic and diastolic blood pressures, as well as dietary recommendations about high-salt containing foods to avoid.

Non-pharmacologic measures can be more effective at lowering blood pressure than medications, as long as children can adhere to recommended treatment and lifestyle changes. As part of a prevention approach, detection of high blood pressure must occur in a timely fashion so that behavioral treatment or lifestyle modification can be implemented.[36] Blood pressure screenings do not always occur at the recommended intervals in the U.S., and many health professionals have difficulties with detection and interpretation of pediatric blood pressures.[37] Pediatric care guidelines need improvement. Early intervention is the key to initiation of successful lifestyle modifications throughout adolescence and into adulthood.

The relationship between excessive dietary sodium intake and higher systolic and diastolic blood pressures has been well established by a number of studies. Since the prevalence of pediatric hypertension in America is increasing, it is imperative to construct cost-effective prevention and treatment plans that involve both policy and individual-level change.

CONCLUSION:

Dramatic rises in the consumption of sugar-sweetened beverages and sodium have occurred particularly in American children and adolescents. Not only have we seen immediate increases in hypertension, diabetes, and dental caries among our kids, but we anticipate continued high consumption of these foods will lead to serious health consequences later in adulthood. As health professionals it is imperative that we develop strategies for lowering the sodium and sugar content in the foods predominantly consumed by children and adolescents. Otherwise we will suffer much more serious consequences such as shortened life expectancy and higher medical costs throughout life.

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Table 1: Sugar-sweetened beverage consumption

Study Characteristics

Ballew et al. (2000)

Study Design: Cross-sectional

Population: Children ages 2-17 (N = 4,070)

Objective: Study connection between beverage choices and adequacy of nutrients in children's diets

Independent Variables: Gender, age, race, SES and total energy intake

Dependent Variables: Beverage type and nutrient intake

Methods: Beverages reported in 24-hour recall records classified as milk, juice, fruit-flavored drinks or carbonated sodas.

Results

1: Correlations Among Beverages

Age Group	**Milk**	**Juice**	**Milk**	**Juice**
	Sodas		Fruit Flavored Drinks	
Boys 2-5	-0.17*	-0.37*	-0.11***	-0.28*
Girls 2-5	-0.18*	-0.26	-0.09***	-0.20*
Boys 6-11	-0.30*	-0.26**	-0.13**	-0.11***
Girls 6-11	-0.28*	-0.20**	-0.12**	-0.08***
Boys 12-17	-0.20*	-0.15**	-0.05	-0.09
Girls 12-17	-0.24*	-0.13**	-0.04	-0.08

* $p \leq 0.0001$ ** $p \leq 0.001$ *** $p \leq 0.01$

2: Adjusted odds ratios of consuming recommended nutrients in relationship to milk among children

Age	Vit. A	Vit. C	B12	Calcium
2-5				
Milk	1.13*	1.01	1.47*	1.37*
Soda	0.97**	0.97**	0.99	0.96***
6-11				
Milk	1.10*	1.03	1.23*	1.35*
Soda	0.98**	0.97	0.96**	0.97**
12-17				
Milk	1.07*	1.03**	1.19*	1.25*
Soda	0.98**	0.99	0.98	0.99

* $p \leq 0.0001$ ** $p \leq 0.01$ *** $p \leq 0.001$

Discussion & Conclusion

Discussion & Conclusion:

- All ages: soda significantly negatively correlated with juice/milk intake
- Consumption of fruit flavored drinks significantly negatively correlated with milk / juice consumption ages 6-11
- Each oz of milk by a child (2-5) increased likelihood of consuming recommended vitamin A
- Each oz of soda consumed by a 2-5 year decreased likelihood of consuming recommended vitamin A
- All age groups, milk positively associated with meeting recommended vitamin A, B12, calcium
- Soda negatively associated with meeting recommended vitamin A for all ages, vitamin C (for ages 2-5), B12 (for ages 6-11) and calcium (2-11)

Limitations:

Possible underreporting, survey bias, vitamin supplement data not collected

<table>
<tr><th>Study Characteristics</th><th>Results</th><th>Discussion & Conclusion</th></tr>
<tr>
<td>
<u>Cohen et al. (2010)</u>

Study Design: Cross-sectional

Population: 3 low-income, high minority, CA communities (N = 1,826)

Objective: Assess discretionary calorie intake and self-reported height/weight and physical activity. Identify most effective approach for community interventions.

Independent variables: Age; trying to lose/maintain weight? Prominence of discretionary foods; physical activity programs; sex, age, race height, weight

Dependent variables: Total energy from discretionary calories; reported BMI

Methods: survey of targeted sites within three communities. Diet measured using questions from Behavioral Risk Factor Survey Study
</td>
<td>
Servings of food in Previous 24 hours
<table>
<tr><th>Avg. Servings in previous 24 hrs</th><th># Servings</th></tr>
<tr><td>Fruits & Veggies</td><td>4.2 servings</td></tr>
<tr><td>Salty snacks</td><td>0.85 servings</td></tr>
<tr><td>Cookies</td><td>0.83 servings</td></tr>
<tr><td>Sugary Beverages</td><td>1.2 servings</td></tr>
<tr><td>Candies</td><td>1.2 servings</td></tr>
</table>

General Data on Respondents
<table>
<tr><td>Ate less than 5 servings of fruits & veggies</td><td>38.7% of respondents</td></tr>
<tr><td>Exercise 150 min/week</td><td>54.4% of respondents</td></tr>
<tr><td>Eat less to control weight</td><td>46% of respondents</td></tr>
</table>
</td>
<td>
Discussion & Conclusion:

Eating significant amount of discretionary calories is more closely tied to BMI than exercise and fruit/vegetable intake
Focusing on consumption of salty snacks/cookies/candy/soda is more promising approach to controlling obesity in these communities
If consumption of discretionary calories is not limited then other types of interventions will be less effective

Limitations:
Recall bias; height/weight self reported; did not address income or education; did not assess all discretionary foods (cakes, pastries). Not rep. of entire community.
</td>
</tr>
<tr>
<td>
<u>Cunnion et al. (2010)</u>

Study Design: Longitudinal study of children & parents visiting dental clinics in Columbus, OH and Washington D.C. Children either were without caries or had early childhood caries.

Population: Parents of 2-8 yr olds (N=501)

Objective: Compare oral health quality of life between children with and without ECC (early childhood caries)

Methods: Administered Pediatric Oral Health Related Quality of Life (POQL) Instrument developed specifically for the study.
</td>
<td>
Mean Impact Scores by Group
<table>
<tr><th>Domain</th><th>ECC</th><th>No ECC</th></tr>
<tr><td>Physical Functioning</td><td>7.9</td><td>0.6*</td></tr>
<tr><td>Mental Functioning</td><td>2.2</td><td>0.2*</td></tr>
<tr><td>Social Functioning</td><td>1.0</td><td>.02*</td></tr>
</table>
*<i>p<0.001</i>, comparing baseline ECC to no ECC

*Parents rating of how bothered their child was in response to an event. Scale 0-14 (highest being the most bothered)
</td>
<td>
Discussion & Conclusion:

ECC children had poorer physical functioning than children w/out caries
Children with ECC's mental functioning more impacted than caries-free children
ECC children had significantly worse social functioning compared to children without caries

Limitations:
Study did not look at barriers to dental care access including insurance, income, distance to dentist
</td>
</tr>
</table>

Study Characteristics | **Results** | **Discussion & Conclusion**

Heller et al. (2001)

Study Characteristics

Study Design: Cross-sectional survey (Third NHANES (National Health and Nutrition Examination Survey) dental and dietary data 1988-1994)

Population: Ages 12+ received dental exam, took a food freq. questionnaire (covered 30 days) and completed interview (diet recall- covered 24 hrs.). (N= 30,818)

Objective: Determine if there is an association between sugary drinks and dental caries

Independent Variables: Age, gender, poverty income ratio, sugared soda consumption

Dependent Variables: DMFS (decayed, missing, and filled permanent tooth surfaces)

Methods: Data from food frequency questionnaires (FFQ) and 24-hour recalls were utilized

Results

Mean Freq. / Quantity of Soda Consumed

Age Group	FFQ (1 month) servings/day	Recall 24 hours serving/day
75+ yrs	.2 servings	.18 servings
55 – 74 yrs	.23 servings	.28 servings
35 – 54 yrs	.46 servings	.63 servings
25 – 34 yrs	.69 servings	.93 servings
17 – 24 yrs	.99 servings	1.2 servings
12 – 16 yrs	.71 servings	1.0 servings
6 -11 yrs	n/a	.67 servings
2 – 5 yrs	n/a	.41 servings

17-24 yrs had highest avg. servings per day.

Soda Consumption / Measures DMFS

Age Group	p value	0 per day	1 per day	2 per day	3 per day
75+ yrs	*p<0.001*	97.5	104	117	117
55 – 74 yrs	*p=0.014*	82.3	85.7	95.3	96.9
35 – 54 yrs	*p=0.019*	48.0	47.9	54.0	62.6
25 – 34 yrs	*p=0.002*	21.0	24.1	24.0	33.8

Discussion & Conclusion:

- More sodas per day → more caries for older age groups (25+ yrs)
- No correlation seen between soda intake/DMFS in the under 25yr groups
- No correlation seen between soda intake and decayed and filled primary surface areas
- Results might show cumulative effect of drinking soda over the years
- Did not see association patterns with consumption of other sugar containing food: cakes, pastries, juice.

Limitations:

Surveys might not portray average diet of participant; recall bias; data only on pat day’s or month’s consumption

Nguyen et al. (2009)

Study Characteristics

Study Design: Cross-sectional NHANES 24-hour recall data, 1999-2004

Population: Children ages 12-18. (N = 4,867)

Objective: Determine if sugar-sweetened drinks increases blood pressure / serum uric acid levels in young people

Independent variables: Weight, age, BMI, height, race/ethnicity, smoking, alcohol, total calories, fiber

Results

1. Uric Acid and sugar beverages*

Sugar Beverages/day	Difference in Serum Uric Acid Levels mg/dL
1-12 oz	0.02 mg/dL
13-24 oz	0.05 mg/dL
25-36 oz	0.16 mg/dL
36+ oz	0.22 mg/dL

trend p = 0.002

Discussion & Conclusion:

- Drinking less sugar-sweetened beverages will benefit young people in terms of cardiovascular effects (no matter what their weight is)
- More sugary beverages consumed, indicates higher level of serum uric acid in adolescents
- Adolescents who drank more sugary sweetened drinks had higher systolic blood pressure
- No association with diastolic blood pressure

Study Characteristics | **Results** | **Discussion & Conclusion**

intake, milk, drinking of diet drinks, sugar sweetened beverages

Dependent variables: Blood pressure and serum uric acid levels

Methods: Constructed linear regression models of sugary beverages and health outcomes

2. Difference in Systolic Blood Pressure based on drinking sugary beverages*

Sugary Beverages/day	Difference in Blood Pressure mm Hg
1-12 oz	0.06 mm Hg
13-24 oz	0.15 mm Hg
25-36 oz	0.11 mm Hg
36+ oz	0.18 mm Hg

trend p = 0.03. ***** no sugar beverages as reference

Limitations:
Survey asked about previous 24 hours, but does not necessarily represent typical diet, or dietary patterns over time.

<u>**Marshall et al. (2005)**</u>

Study Design: Cross-sectional

Population: Children (1-5 years of age). Participants of Iowa Fluoride Study. (N = 645)

Objective: Understand impact of dairy products, juice, and sugar beverages on diet quality in young children

Independent Variables: Gender, family income, age/educational levels of parents

Dependent Variables: Nutrients, food, dairy intake, beverages, NARS (nutrient adequacy ratios)

Methods: Administered 3-day food records to measure diet and beverage intake

1: Median Daily Beverage Intake at 1-5 Yrs

Age	**Milk**	**Juice**	**Soda**
1 year	359g	61g	0g
2 years	327g	142g	0g
3 years	337g	112g	0g
4 years	364g	92g	41g
5 years	340g	73g	41g
p value	*p< 0.01*	*p< 0.01**	*p < 0.01*

2:Milk Intake & Other Beverages (1-5 Yrs of Age)

Beverage	**r**	***p Value***
100% Juice	r = -0.06	p = *0.24*
Water	r = -0.04	*p = 0.44*
Juice Drinks	r = -0.14	*p <0.01*
Soda	r = -0.15	*p < 0.001*
Added Sugar Beverages	r = -0.19	*p < 0.001*

3: Dairy and Non Dairy NARs and % of NARs Dependent on Intake of Dairy Foods (for 1-5 Years)

Nutrient	**Dairy NARs**	**Non Diary NARs**	**(%) Dairy Dependent**
Protein	0.85	1.00	0%
Riboflavin	1.00	1.00	0%
Vitamin D	0.78	0.36	61%
Magnesium	0.56	1.00	0%
Zinc	0.51	1.00	0%
Calcium	0.98	0.31	68%

Discussion & Conclusion

- Milk intake steady over age groups
- Juice intake increased between 1 - 2 years (*p < 0.01*), and slowed after that (*p < 0.06*)*
- Soda consumption increased steadily between 1 and 5 years
- Milk consumption between 1-5 years not associated with 100% juice or water intake
- Milk intake inversely associated w/ consumption of juice drinks, soda, and beverages with added sugar.
- Children do <u>**not**</u> rely on dairy foods for adequate intake of protein, riboflavin, B-12, magnesium and zinc
- Children <u>**do**</u> rely on dairy for adequate intake of vitamin D and calcium
- Dairy dependent % for total diet NARs was 61% for Vitamin D and 68% for Calcium

Limitations:
Survey bias, reporting done by parents/caregivers, families were middle income and educated, and may not be representative of families in poverty

Study Characteristics	Results	Discussion & Conclusion

Study Characteristics

Woong et al. (2008)

Study Design: Cross-sectional third NHANES

Population: Nationally representative US population ages 20+. (N = 14,761)

Objective: Understand the relationship between SSB / diet soda intake and serum uric acid levels

Independent Variables: Daily intake of dairy, meat and seafood; caffeine intake; height, weight, BMI; medication, medical conditions, serum creatinine levels, diet soda, sugar soda, orange juice

Dependent Variables: Serum uric acid levels

Methods: Linear regression estimated relationship between serum uric acid and consumption of sugar beverages and diet soda. Used logistic regression to evaluate clinically high uric acid (>7.0 mg/dl men; >5.7 women)

Results

Soda Intake / Serum Uric Acid

Soda Intake Servings/day	Serum Uric Acid Level*	Serum Uric Acid Level**
<0.5	0.12 mg/dl	0.08 mg/dl
0.5-0.9	0.20 mg/dl	0.15 mg/dl
1-3	0.38 mg/dl	0.33 mg/dl
≥4	0.45 mg/dl	0.42 mg/dl
	p < 0.001	*p < 0.001*

Diet Soda Intake / Serum Uric Acid

Diet Soda Servings/day	Serum Uric Acid Level*	Serum Uric Acid Level**
<0.5	-0.08 mg/dl	-0.03 mg/dl
0.5-0.9	-0.22 mg/dl	-0.14 mg/dl
1-3	-0.17 mg/dl	-0.07 mg/dl
≥4	-0.28 mg/dl	-0.12 mg/dl
	p = 0.001	*p = 0.131*

*Adjusted for: age, sex, smoking, BMI, diuretics, beta blockers, hypertension, GFR

**Additionally adjusted for: alcohol, meat, seafood, coffee, dairy, tea, caffeine, energy

Discussion & Conclusion

Discussion & Conclusion

- As soda intake increased, serum uric acid levels significantly increased
- The association was independent of sex, age, BMI, and other covariates.
- Association persisted across subgroups grouped by sex, age, BMI, alcohol, meat, dairy.
- The highest soda intake levels (≥4) showed increases in serum uric acid by 0.45 and 0.42 mg/dl
- Diet soda consumption was inversely associated with serum uric acid levels*
- Further adjustments**, were insignificant

Limitations:

Surveys are cross-sectional and therefore not conclusive in terms of exposure and measurement of uric acid

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Study Characteristics

van der Horst et al. (2007)

Study Design: cross-sectional study contained within the Dutch Obesity Intervention in Teenagers

Population: secondary school students (N=383)

Objective: study whether SSB intake is associated with parenting style/practices

Methods: administered questionnaires to evaluate beverage intake, diet, parent practices. Multiple linear regression analyses used to evaluate association between parenting and sugar beverage consumption.

Results

1. Associations: Cognition & SSB Intake

Cognitions	Multivariate: β* / *p value*
Attitude	189.3 / *p*<0.001
Self-efficacy	-128.2 / *p*<0.001
Parent modeling	191.2 / *p*<0.001

*β: unstandardized coefficient—shows change in SSB consumption (in ml)

**Adjusted for age, gender and ethnicity and further adjusted for cognitions.

2. Association Between Parenting Practices and Daily SSB Consumption

β (ml day^{-1})	95% CI	*p value*
-31.3 ml	-41.3, -21.3	*p*<0.001

* Model adjusts for age, gender, ethnicity, modeling from parents

Discussion & Conclusion

Discussion & Conclusion

- Attitude, self-efficacy and modeling from parents significantly associated with SSB intake
- Consuming less SSBs was associated with adolescents who reported strict parenting practices

Limitations:

Study design was cross-sectional. Measures of parenting practice were self-assessed and may not be objective.

Table 2: Sodium intake and hypertension in American children and adolescents

<table>
<tr><th>Study Characteristics</th><th>Results</th><th>Discussion & Conclusion</th></tr>
<tr>
<td><u>Hofman et al. (1983)</u>
Study Design: Double-blind randomized trial

Population:
• Infants born at home or in outpatient clinics in Zoetermeer (suburban residential area) in Netherlands
• N = 476 (245 babies in control (normal sodium diet); 231 babies low-sodium diet (intervention)
• Baseline characteristics of the two groups were very similar (weight and length at birth, parental blood pressure) was a successful randomization

Objectives: Effect of dietary sodium on blood pressure in infants (first six months of life)

Independent Variables: Amount of sodium in diet (formula milk and solids)

Dependent Variables: Systolic blood pressure

Other variables: Different types of sodium intake (breast milk versus solid foods)

Methods
• Blood pressure measured at weeks 1, 5, 9, 13, 17, 21, 25 for control and intervention
• Measurements taken at similar times and while babies were awake and not crying
• 4 in control and six in intervention excluded due to death, severe illness, and migration</td>
<td>Composition of Intervention:
<table>
<tr><th></th><th>Control
(n = 245)</th><th>Intervention/
Low Sodium
(n = 231)</th></tr>
<tr><td>Formula milk sodium</td><td>19.2 mmole/L (regular)</td><td>6.3 mmole/L (low)</td></tr>
<tr><td>Sodium in vegetables</td><td>22.6 to 76.5 mmole/L</td><td>2.2 to 13.9 mmole/L</td></tr>
<tr><td>Sodium in formula milk</td><td>72%</td><td>72%</td></tr>
<tr><td>Sodium from solids</td><td>18%</td><td>5%</td></tr>
<tr><td>Sodium from breastmilk</td><td>10%</td><td>23%</td></tr>
</table>

Bivariate statistics:
• Systolic blood pressure 2.0 mm Hg lower in low-sodium group compared to control group at 25 weeks ($p = 0.03$)

Multivariate statistics:
• Systolic blood pressure 2.1 mm Hg lower in low-sodium group at 25 weeks ($p = 0.01$) when adjusted for observers, weight, length at birth, systolic blood pressure measured in first week</td>
<td>Discussion & Conclusion:
• Recordings show similar amounts of deviation from protocol between groups.
• Possible dose response relation, because the difference between blood pressures of control and intervention groups increased as time went on
• Increased sodium intake → increase in extracellular fluid volume
• Sodium may directly control peripheral vascular resistance (through calcium)
• Body weights were similar between the two groups, leading to suspicion that sodium directly affects peripheral vascular resistance
• Supports causal nature of sodium on blood pressure within pediatric population → more reason to look towards preventative measures of high blood pressure
• Importance in reaching a large (two to threefold difference) difference in amounts of sodium between control and intervention groups (low sodium group had three times less sodium than control)

Limitations:
Babies born in hospital were not included. Study may have excluded hypertensive mothers and babies who are susceptible to higher blood pressure with increased dietary sodium</td>
</tr>
<tr>
<td><u>Johnson et al. (1994)</u>
Study Design: Cross-sectional

Population:
• N = 933 adolescents: 11 and 18 years old</td>
<td>Results:
• Male adolescents with male head of household: highest percent of calories from fat
• Southern males had highest sodium
• Females: low essential vitamins and minerals</td>
<td>Discussion & Conclusion
• Over consumption of fat, saturated fat and sodium across general population
• Income does not appear to influence nutritional quality</td>
</tr>
</table>

Study Characteristics

- 53% female, 47% male
- 79% white, 14% black, 7% other-various
- degrees of urbanization in different geological regions, with an annual median income of $24,480

Objectives: Examine dietary intake in adolescents to evaluate nutritional deficiencies (according to recommended values) based on sociodemographic variables

Independent Variables: Socio demographic

Dependent Variables: Dietary intake of sodium, and other nutrients

Other variables: Snacking, irregular eating habits, eating on the go, appearance, peer and cultural influences, household income and site, race, geographic region, urbanization, head of household status

Methods:

Data Collection:

- 24-hour recall, 2-day food record (self- reported) analyzed separately by gender compared to the National Research Council and National Institutes of Health standards

Multivariate statistics:

- multivariate associations with dietary intake and quality of diet (ANCOVA)

Results

- Females with male head of household: lowest percent of calories from fat

- Southern females: lowest (nutrient adequacy ratio (NAR) for vitamin A, calcium, magnesium, and potassium
- Black and white males and black females highest intake of cholesterol

Nutrient	Sex	Recommended Intake	Mean Intake	% Tot Cal
Total Fat		≤ 30% cal		
	Males		93g	37
	Females		69g	37
Saturated Fat		≤ 10% cal		
	Males		36g	14
	Females		26g	14
Cholesterol		≤ 300 mg		
	Males		328 mg	
	Females		241 mg	
Sodium		≤ 2400 mg		
	Males		3865 mg	
	Females		2836 mg	

Discussion & Conclusion

- Education is an effective method to prevent nutrient deficiencies or habits that can lead to osteoporosis, poor growth, development of iron deficiencies, cancer, or other chronic diseases
- Everyone at high risk for excess fat intake
- Ethnic differences related to cultural eating habits can lead to chronic disease (excess sodium intake in “other” ethnicity related to hypertension as adults in those ethnicities)

Limitations:

- No data to show whether non-response bias played a role in the study.
- Not enough diversity (93% of population was either black or white).
- Lowest income families and homeless people were not included in the study. More research is needed in these high risk groups.

<table>
<tr><th>Study Characteristics</th><th>Results</th><th>Discussion & Conclusion</th></tr>
<tr><td><u>Malaga et al. (2003)</u>

Study Design: Cross-sectional design of taste sensitivity

Population:
N = 72, (42 boys, 30 females)
Healthy Spanish teens: 9 to 21 years of age
Clinical, anthropometric, biochemical parameters within normal range
Objectives: Does gustatory (taste) sensitivity to sodium affect blood pressure?

Independent Variables: Gustatory perception/sensitivity, gender, height, BMI

Dependent Variables: Blood pressure

Methods:
Taste sensitivity test: recognize distilled from deionized water, in low sodium conditions
Taste discrimination test: six different saline solutions given in random order</td><td>Bivariate statistics:
Association between systolic blood pressure & sodium sensitivity ($p < 0.01$, r = -0.33)
No significant association between diastolic blood pressure and sodium sensitivity
Discrimination score and salt sensitivity correlated (r = 0.27, $p < 0.05$)
Multivariate statistics:
Association between sodium sensitivity and systolic blood pressure increased when controlled for body weight (r = -0.56, $p < 0.001$)</td><td>Discussion & Conclusion
Higher salt threshold had lower detection
Teens with high systolic blood pressure had high sensitivity to sodium (lower detection threshold)
Data from males and females grouped and studied together because blood pressures were in the normal range and were similar
Use of NaCl dissolved in water prevented personal preferences for certain types of salty foods from interfering with salt discrimination
The higher the systolic blood pressure, the higher the salt threshold
Limitations:
Small sample size, only one ethnicity, may not generalize to other ethnic groups</td></tr>
</table>

Study Characteristics	Results	Discussion & Conclusion

Study Characteristics

<u>Tuthill et al. (1981)</u>

Study Design: Cross-sectional study of 2 communities

Study Characteristics:

- High sodium group: 346 people
- Low sodium group: 262 people-blood pressure taken by same nurses, results blind between nurses, controlled for diurnal variation by screening both communities similarly in the morning and afternoon

Population:

- Third grade students from two communities, one community with 108 mg/L of sodium in the drinking water, and another with 8 mg/L sodium in the drinking water
- Two communities similar in sociodemographic factors that may influence blood pressure (median income, education, ethnicity, size)
- Main difference is sodium concentration in drinking water

Objectives: Do higher levels of sodium in drinking water contribute to a higher blood pressure among third grade students?

Independent Variables: Dietary intake and urinary excretion of sodium

Dependent Variables: Blood pressure

Other variables: Family history and a genetic susceptibility to high blood pressure

Methods: Bivariate and multivariate linear regression controlled for height, weight, and SES using single socioeconomic scale and Hollingshead scoring system

Results

Descriptive statistics:

	High Sodium Group (*n* = 346)	Low Sodium Group (*n* = 262)
Completed 24 hour dietary diary	90.2%	91.6%
Provided Urine Sample	72% male, 70% female	76% male, 62% female

Adjusted Differences in Sodium Intake and Blood Pressure Between Individuals Residing in High and Low Sodium Communities

Male Systolic	Female Systolic	Male Diastolic	Female Diastolic	Mean Sodium	p-val
3.7	3.8	3.2	4.5	347mg	0.035

Summary of Results:

- Dietary sodium in high sodium group is 13% higher, potassium 8% higher; calcium 20% higher in males and 16% higher in females
- Once water is included with dietary intake, the differences in sodium intake increases to 24.4% for males and 25.5% for females

Bivariate statistics (unadjusted):

- 2.6 mm Hg difference for systolic blood pressure ($p = 0.023$)
- 3.6 mm Hg difference for diastolic blood pressure ($p = 0.002$)

Multivariate statistics (adjusted):

- Multivariate adjustment increased difference in blood pressure between the communities

Discussion & Conclusion

- Conclusions based on a community level were significant and point out important changes that can be made to improve health
- Overall significant difference in mean blood pressure between high sodium community and low sodium community for systolic and diastolic pressures
- U.S. Environmental Protection Agency: limit amount of sodium allowed in drinking water based on heath risks of excessive sodium intake and increased blood pressure
- If screening can be used to determine who has a genetic predisposition to high blood pressure can then study individual blood pressure differences as well as community level differences.
- Further research: how gastrointestinal tract absorbs sodium originating from fluids versus solid foods
- Chronic (daily) exposure to increased sodium levels is a more significant heath problem then recent increased levels
- Important to intervene if prevention of high blood pressures is possible by lowering sodium concentration in drinking water

Limitations:
Other elements in water (besides sodium) may have an effect on blood pressure, difficult to determine who has a genetic predisposition to high blood pressure without drawing blood samples

Study Characteristics	Results	Discussion & Conclusion
<u>Wang et al. (2010)</u> **Study Design:** Simulation model, longitudinal correlation analyses/ecologic data from various sources **Population:** U.S. adolescents, 15 years old **Objectives:** determine effectiveness of blood pressure screening among U.S. adolescents **Independent Variables (3 approaches):** • No intervention • Screen and treat: • Population-wide strategy: reduce blood pressure by dietary sodium intake and physical education **Dependent Variables:** Cardiovascular health **Other variables:** Ethnicity, geographic location **Methods:** • Simulated cohort of 2,065,127 boys and 1,952,694 girls, used estimates from Framingham Offspring Study to assign cohort blood pressure distribution • Cost and treatment effectiveness from various sources (meta-analysis, published data)	**Bivariate Statistics:** • Treating high risk adolescents (marked by left ventricular hypertrophy) was the most cost-effective treatment at $18,000/ QALY for males and $47,000/ QALY for females • Increasing physical education projected at $11,000/ QALY for males and $35,000 / QALY for females • Individual based exercise programs $55,000/ QALY for males and $120,000/ QALY for females	**Discussion & Conclusion** • Routine and selective screening strategies are more costly than population-wide approaches • Effective in terms of effort and money to prevent hypertension at adolescence, rather than treating hypertensive adults • Intervention using broad-based population techniques would be cost-effective in the long run, e.g. increase physical education in schools • Routine blood pressure screenings of adolescents moderately effective; not most cost-effective; implement high risk screenings • Further research: examine cause for gaps in treatment costs for males and females **Limitations**: Assumptions or estimates may not be accurate: cost or predicted percent of population needing specific procedures or antihypertensive drugs as adults. No individual data and therefore subject to ecologic bias.