

## Fluid Consumption and Ambient Temperature among Children in the United States: Implications for Water Fluoridation Policy

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## Optimal Water Fluoride Concentration (1 ppm F)

- Dean's 21-cities study (1941, 1942)
  - Maximize dental caries prevention
  - Acceptable level of dental fluorosis
- Community Trials of Water Fluoridation
  - Grand Rapids-Muskegon (1945)
  - Newburgh-Kingston (1945)
  - Evanston-Oak Park (1946)



"Still Water" Grand Rapids, MI

## Adjustment of Water Fluoride Concentration

- Recommended concentration range by ambient temperature
  - Arnold (1943)
  - Galagan and Lamson (1953)
  - Galagan et al (1957)
  - Galagan and Vermillion (1957)
  - US Public Health Service (1962)

## Ambient Temperature and Fluid Intake Galagan DJ et al. (1957)

- Antioch, CA (n=316), Brentwood, CA (n=139)
- 0-10 year-old children
- 5-day fluid intake measurement
  - Drinking water, formula preparations/reconstitution
  - Soup and other water-based beverages
  - Carbonated beverages, juices, and milk
  - \*\*Water used in cooking was not recorded
- 5-day mean daily maximum temperature (°F)

## Determining Optimum Fluoride Concentrations Galagan DJ and Vermillion JR (1957)

- From Antioch and Brentwood, CA:  
 $E [Water (oz) per body weight (lb)] = -0.038 + 0.0062 \text{ temperature } (°F)$

**"The validity of this equation should perhaps be checked ... in other areas of the country, ..."**

- From known optimal F levels and temperature:  
 $Parts \text{ per million Fluoride} = 0.34 / E$

## Adjustment of Water Fluoride Concentration – USPHS 1962

Annual Average of Maximum Daily Temperature (°F)*	Recommended optimum fluoride concentration (ppm)
50.0 – 53.7	1.2
53.8 – 58.3	1.1
58.4 – 63.8	1.0
63.9 – 70.6	0.9
70.7 – 79.2	0.8
79.3 – 90.5	0.7

\* Based on temperature data obtained for a minimum of 5 years.

### Research Question

- Since these studies were conducted, social and technological changes have affected people's way of living with an effect on fluid consumption:
  - Air conditioning & central heating
  - Transportation
  - Exercise & outdoor activities

Q: Is fluid (and water) consumption still related to ambient temperature?

### Changes in the Pattern of Fluid Intake Heller et al. 1998; 1999; Sohn et al. 2001; 2009

- Increase of carbonated beverages and juices
- Increase of factory-processed food
- Decrease of water and milk
- Other factors to consider
  - Bottled water
  - Home water conditioning/filtering systems

### Other Factors Supporting a Revisiting of Current F Recommendations

- Decrease in dental caries in permanent teeth
- Increase in enamel fluorosis
- Higher fluoride intake
  - Multiple and diverse fluoride sources
  - Changing patterns of fluid intake
  - Beverages manufactured with fluoridated water
- Changes in living condition
- Global warming!?

### Rationale: Recommendations for using Fluoride (CDC), 2001

"The current method of determining the optimal concentration of fluoride in community drinking water, which depends on the average maximum annual ambient temperature, should be re-evaluated because of the social and environmental changes that have occurred since it was adopted in 1962. Research into current consumption patterns of water, processed beverages, and processed foods is also needed."

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#### Fluid Consumption Related to Climate among Children in the United States

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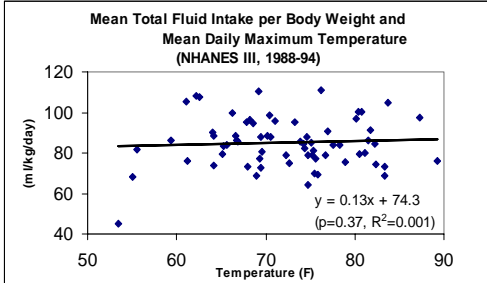
#### Specific Aims

1. To investigate the relationship between fluid consumption and ambient temperature
2. To investigate the relationship between fluid consumption patterns and sociodemographic factors

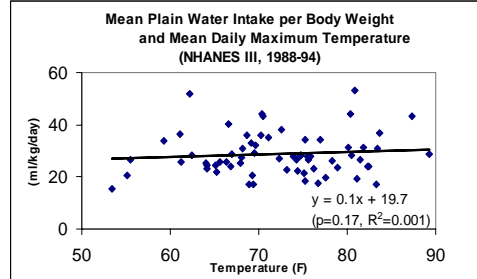
#### Methods: Overview

- NHANES III 24-hour dietary recall interview
  - Children aged 1-10 years
  - Proxy respondents
  - English & Spanish
  - Validation by an interviewer - reliable answers
- NHANES III dietary data files
  - Total Nutrient Intake
  - Individual Foods File
- Ambient temperature data
  - National Oceanic & Atmospheric Administration
  - Monthly average of 30-year (1961-1990) mean of daily maximum temperature

## Fluid Consumption and Local Climate



## Fluid Consumption and Local Climate



## Amount of fluid intake and local climate

Table 4. Multiple regression models of fluid intake per body weight among children aged 1-10 years in NHANES III (1988-1994). (n=3,250)

Variable	Total Fluid Intake (ml/kg/day)			Plain Water Intake (ml/kg/day)		
	$\beta$	S.E.( $\beta$ )	P-value	$\beta$	S.E.( $\beta$ )	P-value
Age	-6.66	0.35	<0.01	-0.55	0.19	0.01
Sex						
Male	0	0	-	0	0	-
Female	-4.56	1.86	0.02	-2.61	1.45	0.08
Race/ethnicity						
White	0	0	-	0	0	-
Black	4.28	2.82	0.14	8.90	1.75	<0.01
Mexican American	3.45	2.04	0.10	1.35	1.59	0.40
Others	3.09	3.18	0.34	-2.18	2.13	0.31
SES						
Low	0	0	-	0	0	-
Middle	-7.06	2.77	0.01	-4.52	1.93	0.02
High	-10.18	3.34	<0.01	-7.65	2.33	<0.01
Maximum daily temperature	0.06	0.13	0.66	0.03	0.07	0.70
R-square	0.26			0.05		

## Limitation: NHANES III

- 24-hour dietary recall interview
  - High Intra individual variation
  - Use of proxy respondents
  - Tendency to underestimate consumption
- Biased by season and region
  - Limited calendar schedule for MEC visits (Inability to compare region and season variables)
  - Absence of extreme temperatures (Truncated temperature range (53.4 - 89.3 °F))
- Limited release of location and time information
  - Loss of samples - generalizability, bias
  - Use of 30-year mean temperature data for the month

## Consistency of fluid intake analysis between NHANES III (1988-94) and NHANES 1999-2004

### CDC Fluoride Expert Panel

Brian Burt, Jay Kumar, Steve Levy, Jane McGinley, Howard Pollick, Gary Rozier, John Stamm & Gary Whitford

## Overview

Previous analysis (Sohn et al.)	2007-2008 analysis
<b>Fluid intake data</b> NHANES III 1988-1994	<b>Fluid intake data</b> NHANES 1999-2004
<b>Public release datasets</b> -Series11, No 1A (1997) - Home interview, MEC Examination, Dietary Interview -Series11, No 2A (1998) - Additional dietary data, Vitamin & Medicine data	<b>Public release data sets:</b> demographics, dietary recall  <b>Restricted data sets:</b> true strata, true PSU, and true weights -Public release data masks true geography, public release weights based on masked geography
True strata and true PSU, but only largest 35 counties in sample identified	
<b>Climate data</b> NOAA NWS temperature -free, public data -US National Climatic Data Center (Internet) -30-year normals -assigned PSU/county temperature from a nearby municipal building or airport	<b>Climate data</b> NOAA NWS temperature -fee data, via interagency agreement -US National Climatic Data Center -actual maximum daily temperature -average of stations in county

## 24-hour Dietary Recall Data

### 1988-1994

- 24-hour dietary recall interview
  - Proxy respondents
  - English & Spanish
  - Validation by an interviewer - reliable answers
  - Use USDA nutrient database and food code

- Dietary data files
  - Total Nutrient Intake
  - Individual Foods File
- Public release data sets

### 1999-2004

- 24-hour dietary recall interview
  - Same as 1988-1994 except
  - USDA CSFII merged with NHANES
  - Protocol changes:
    - Evaluation, then addition of phone interview for 2<sup>nd</sup> 24-hr recall
    - This analysis used only 1<sup>st</sup> day MEC-collected recall

- Dietary data files
  - Total Nutrient Intake
  - Individual Foods File
- Public release data sets

## Classification of fluid sources

### Sohn et al 1988-1994

- Plain water (tap/spring)
- Coffee & tea
- Carbonated drinks
- Juice
- Milk
- Moisture from other food & beverages

Total Fluid = Sum of all above  
(as calculated by NCHS)

### 2007-2008 of 1999-2004

- Plain water (tap/spring/bottle)
- Water based/added
- Soft drinks (soda/sports)
- Juice
- Milk
- Moisture from other foods & beverages

Total Fluid = Sum of all above  
(as calculated by NCHS)

## Ambient temperature data

### 1988-1994

- NOAA NWS temperature
  - free, public data - Internet
  - US National Climatic Data Center
  - 30-year normals 1961-1990
  - assigned PSU/county temperature from a nearby municipal building or airport
- Could only assign temperatures for 35 largest counties identified in public release NHANES data

### 1999-2004

- NOAA NWS temperature
  - fee data - interagency use
  - US National Climatic Data Center
  - actual maximum daily temperature 1999-2005
  - average of stations located in each county
- Not all counties had an NWS weather station in the county
- Also used county averages for 30-year normals 1970-2000

## Total fluid intake and ambient temperature

Variable	Total fluid intake (mg/kg/day)					
	1988-1994 n=3,250			1999-2004 n=4,107		
	$\beta$	S.E.( $\beta$ )	P-value	$\beta$	S.E.( $\beta$ )	P-value
Age	-6.66	0.35	<0.01	-8.37	0.78	<0.01
Sex						
Male	0.00	0.00	—	0.00	0.00	—
Female	-4.56	1.86	0.02	0.76	4.06	0.85
Race/ethnicity						
White*	0.00	0.00	—	0.00	0.00	—
Black*	4.28	2.82	0.14	-3.47	4.13	0.41
Mexican American	3.45	2.04	0.10	1.31	5.40	0.81
Others**	3.09	3.18	0.34	2.47	2.63	0.36
SES Poverty Income Ratio						
Low <1.3	0.00	0.00	—	0.00	0.00	—
Middle 1.3-3.4	-7.06	2.77	0.01	-13.38	5.70	0.03
High 3.5	-10.18	3.34	<0.01	-8.19	4.92	0.11
Maximum daily temperature	0.06	0.13	0.66	0.12	0.19	0.52
R-square	0.26			0.32		

\*Not Hispanic

\*\*Data collection for race/ethnicity changed between cycles - Others is other races/other Hispanic in NH3 and Other races/other Hispanic/ and multiple races in NH4

\*\*\*NHANES III analysis used 30-year normals. NHANES 1999-2004 used actual maximum daily temperature for date of fluid intake.

## Plain water intake and ambient temperature

Variable	Plain water intake (mg/kg/day)					
	1988-1994 n=3,250			1999-2004 n=4,107		
	$\beta$	S.E.( $\beta$ )	P-value	$\beta$	S.E.( $\beta$ )	P-value
Age	-0.55	0.19	0.01	-1.29	0.28	<0.01
Sex						
Male	0.00	0.00	—	0.00	0.00	—
Female	-2.61	1.45	0.08	3.06	2.04	0.14
Race/ethnicity						
White*	0.00	0.00	—	0.00	0.00	—
Black*	8.90	1.75	<0.01	3.61	3.40	0.30
Mexican American	1.35	1.59	0.40	0.64	2.18	0.77
Others**	-2.18	2.13	0.31	-2.00	2.34	0.40
SES Poverty Income Ratio						
Low <1.3	0.00	0.00	—	0.00	0.00	—
Middle 1.3-3.4	-4.52	1.93	0.02	-2.31	2.24	0.31
High 3.5	-7.65	2.33	<0.01	1.78	2.74	0.52
Maximum daily temperature	0.03	0.07	0.70	0.13	0.12	0.27
R-square	0.05			0.04		

\*Not Hispanic

\*\*Data collection for race/ethnicity changed between cycles - Others is other races/other Hispanic in NH3 and Other races/other Hispanic/ and multiple races in NH4

\*\*\*NHANES III analysis used 30-year normals. NHANES 1999-2004 used actual maximum daily temperature for date of fluid intake.

## Limitations

### Modeling approach

- R-square low, really low for plain water
- Distribution of respondents still biased by month and annual temperature zone
- Temperature assigned at county level
  - Census tract level temperature may improve this somewhat, but temperature not available for all census tracts

## Conclusions

- There is no evidence that fluid consumption is significantly related to local climate in contemporary conditions
- The national temperature-related guidelines for fluoride concentration in drinking water may be due for re-evaluation
- Relationship between sociodemographic factors and children's fluid consumption patterns is not consistent over time

## Future Analysis

- NHANES 1988-1994 + 1999-2004
  - allows testing for time trends
- Restricted, geocoded data for 1988-1994+1999-2004
  - Allows use of complete 1988-1994 data set
  - Allows better matching of temperature and other climate data to geography in both cycles
- NHANES may have sufficient data to answer some, **but not all**, questions important for re-evaluation of criteria for concentration of fluoride in drinking water

Thank you! Questions?



In Memory of Dr. Herschel S. Horowitz

## Fluoride in bottled water & temperature

TABLE 3. U.S. Food and Drug Administration (FDA) fluoride requirements for bottled water packaged in the United States

Annual average of maximum daily air temperature (F) where the bottled water is sold at retail	Maximum fluoride concentration (mg/L) allowed in bottled water	
	No fluoride added to bottled water	Fluoride added to bottled water
≤53.7	2.4	1.7
53.8-58.3	2.2	1.5
58.4-63.8	2	1.3
63.9-70.6	1.8	1.2
70.7-79.2	1.6	1
79.3-90.5	1.4	0.8

**Note:** FDA regulations require that fluoride be listed on the label only if the bottler adds fluoride during processing; the bottler is not required to list the fluoride concentration, which might or might not be optimal. FDA does not allow imported bottled water with no added fluoride to contain >1.4 mg fluoride/L or imported bottled water with added fluoride to contain >0.8 mg fluoride/L.

**Source:** US Department of Health and Human Services, Food and Drug Administration. 21 CFR Part 165.110. Bottled water. Federal Register 1995;60:57124-30.