Sugar-Sweetened Beverages & Health: Where does the Evidence Stand?

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Department of Nutrition
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Overview

- **Background**
- **Epidemiological Data**
  - SSB and Obesity
  - SSB and Diabetes
  - SSB and Cardiovascular Risk
- **Potential Biological Mechanisms**
- **Conclusions**
- **Questions**
Worldwide, 1.6 billion people were overweight vs. 0.8 billion were underweight

In 2005

THE WORLD IS FAT

More people in the developing world are now overweight than hungry. How can the poorest countries fight obesity?

By Barry M. Popkin

Over the past 20 years a dramatic transition has altered the diet and health of hundreds of millions of people across the Third World. For most developing nations, obesity has emerged as a more serious health threat than hunger. In countries such as Mexico, Egypt and South Africa, more than half the adults are either overweight (possessing a body mass index, or BMI, of 25 or higher) or obese (possessing a BMI of 30 or higher). In virtually all of Latin America and much of the Middle East and North Africa, at least one out of four adults is overweight. Although undernutrition and famine remain significant problems in sub-Saharan Africa and South Asia, even desperate poor countries such as Nigeria and Uganda are wrestling with the dilemma of obesity. Worldwide, more than 1.3 billion people are overweight, whereas only about 800 million are underweight—and these statistics are diverging rapidly.

The obesity rates in many developing countries now rival those in the U.S. and other high-income nations. What is more, the shift from undernutrition to overnutrition—often called the nutrition transition—has occurred in less than a generation. When I return to villages that I visited 15 years ago in India, China, Mexico and the Philippines, I see enormous changes: kids guzzle soft drinks and watch television, adults ride mopeds instead of walking and buy their food from supermarkets. In addition to adopting more sedentary lifestyles, people in the developing world are also consuming more caloric sweeteners, vegetable oils and animal-source foods (meat, poultry, fish, eggs and dairy products). The combination of lifestyle and dietary changes has paved the way for a public
Worldwide age-standardized prevalence of overweight (upper) and obesity (lower) in adults 20 years and older by country in 2005.
In 2010 11.7% overweight in developed countries and 6.1% in developing countries.

Percentage change b/w 1990 and 2010: 65% in developing countries and 48% in developed countries.

Defined as > 2 SDs above WHO weight-for-height median
Medical Complications of Obesity

- Pulmonary disease
  - abnormal function
  - obstructive sleep apnea
  - hypoventilation syndrome

- Nonalcoholic fatty liver disease
  - steatosis
  - steatohepatitis
  - cirrhosis

- Coronary heart disease
- Diabetes
- Dyslipidemia
- Hypertension

- Gynecologic abnormalities
  - abnormal menses
  - infertility
  - polycystic ovarian syndrome

- Gall bladder disease

- Gout

- Osteoarthritis

- Skin

- Phlebitis
  - venous stasis

- Cancer
  - breast, uterus, cervix
  - colon, esophagus, pancreas
  - kidney, prostate

- Severe pancreatitis

- Idiopathic intracranial hypertension
- Stroke
- Cataracts
In 2009, care of diabetes and related complications lead to $113 billion in direct medical costs (2007 US dollars)

Diabetes Care 32:2225-2229, 2009
US Trends in per Capita Calories from Beverages

Data for 1965-2002 are from Duffey and Popkin, 2007; data for 2005-2006 are from Brownell et al, 2009

In Canadian children age 2-18 years SSB contributed between 2% and 18% of total energy in 2004 (Canadian Community Health Survey)

Global Trends

Change in Total Volume of Carbonated Soft Drinks Consumed Between 2002 and 2007

% change in volume of soft drinks consumed, 2002-2007

US
Australasia
Western Europe
Asia Pacific
Middle East and Africa
Latin America
Eastern Europe

SSB:

• Soft drinks, fruit drinks, energy drinks, iced tea, lemonade, cordials, punch

• composed of energy-containing sweeteners such as sucrose, high-fructose corn syrup, or fruit juice concentrates

Non SSB:

• 100% fruit juice and not blended with added sweeteners is not considered an SSB.
Soft drink ingredients

• Energy: 12-14 kcal/ounce
  or ~150 kcal/12 oz can

• Sugars: 3.1-3.6 g/ounce
  or ~ 40-50 g sugar/12 oz can
  (~10 tsp/12 ounce can)

• Glycemic index: 63 (with glucose as reference)

If these calories are added to the typical US diet, 1 can of soda per day could lead to a weight gain of 15 lb in 3 yrs.
Forrest plot of studies evaluating SSB consumption and adiposity in children, per change in BMI units for each 12-oz serving per day change in SSB

Fixed Effects: 0.03 (0.01, 0.04)  
Forrest plot of studies evaluating SSB consumption and adiposity in children per change in BMI units for each 12-oz serving per day change in SSB

FIGURE 1. Forest plot of studies of sugar-sweetened beverage (SB) consumption and BMI (in kg/m²) in children and adolescents.
Preventing childhood obesity by reducing consumption of carbonated drinks: cluster randomised controlled trial

Janet James, Peter Thomas, David Cavan and David Kerr

*BMJ* 2004;328;1237; originally published online 23 Apr 2004; doi:10.1136/bmj.38077.458438.EE

**Fig 2** Mean change in prevalence of overweight and obese children from baseline to follow up at 12 months according to clusters

N=644 from 6 schools
Regular Sugar-Sweetened Beverage Consumption between Meals Increases Risk of Overweight among Preschool-Aged Children

Sugar-sweetened beverages and weight gain over time: Nurses’ Health Study II (N > 50,000)

Adjusted for characteristics at each time point

Schulze et al. JAMA 2004
Soft Drink and Juice Consumption and Risk of Physician-diagnosed Incident Type 2 Diabetes

The Singapore Chinese Health Study

\[ N = 43,580 \]

Mean weight change 0.10 kg. Participants in highest category had increase of 0.53 kg compared with infrequent users.
A reduction in SSB intake of 1 serving/d was associated with a weight loss of 0.49 kg (95% CI: 0.11, 0.82; P = 0.006) at 6 mo and of 0.65 kg (95% CI: 0.22, 1.09; P = 0.003) at 18 mo.

Chen et al. AJCN 2009
Relationships between Changes in Food and Beverage Consumption and Weight Changes Every 4 Years, According to Study Cohort.

N=120,877

Within each 4-year period, participants gained an average of 3.35 lb

Replacing caloric beverages with water or diet beverages for weight loss in adults: main results of the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial\textsuperscript{1–4}

Deborah F Tate, Gabrielle Turner-McGrievy, Elizabeth Lyons, June Stevens, Karen Erickson, Kristen Polzien, Molly Diamond, Xiaoshan Wang, and Barry Popkin
Forrest Plot of Studies Evaluating SSB intake and Risk of Type 2 Diabetes

Malik et al. 2010. Diabetes Care. 33:2477-2483

Fixed-effects estimate: RR 1.25 (1.17, 1.32)

Omitting 3 studies that adjusted for BMI and total energy:
Random effects: RR 1.28 (1.13, 1.45)

N= 310, 819
15, 043 cases
<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Age (y)</th>
<th>Duration (y)</th>
<th>Outcome</th>
<th>Results</th>
<th>Adjust energy / BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montonen, 2007</td>
<td>2,360 Finland</td>
<td>40-69</td>
<td>12</td>
<td>T2DM</td>
<td>+</td>
<td>Y</td>
</tr>
<tr>
<td>Paynter, 2006</td>
<td>12,204 ARIC, USA</td>
<td>45-64</td>
<td>9</td>
<td>T2DM</td>
<td>M + NS</td>
<td>W + NS</td>
</tr>
<tr>
<td>Schulze, 2004</td>
<td>91,249 NHS II, USA</td>
<td>24-44</td>
<td>8</td>
<td>T2DM</td>
<td>+</td>
<td>N</td>
</tr>
<tr>
<td>Palmer, 2008</td>
<td>43,960 BWHS, USA</td>
<td>21-69</td>
<td>10</td>
<td>T2DM</td>
<td>+</td>
<td>N</td>
</tr>
<tr>
<td>Bazzano, 2009</td>
<td>71,346 NHS, USA</td>
<td>38-63</td>
<td>18</td>
<td>T2DM</td>
<td>+</td>
<td>Y</td>
</tr>
<tr>
<td>Nettleton, 2009</td>
<td>5,011 MESA, USA</td>
<td>45-84</td>
<td>5</td>
<td>T2DM</td>
<td>- NS</td>
<td>Y</td>
</tr>
<tr>
<td>Odegaard 2010</td>
<td>43,580 Singapore Chinese Health Study</td>
<td>45–74</td>
<td>5.7</td>
<td>T2DM</td>
<td>+</td>
<td>N</td>
</tr>
<tr>
<td>De Koning, 2010</td>
<td>41,109 HPFS, USA</td>
<td>40–75</td>
<td>20</td>
<td>T2DM</td>
<td>+</td>
<td>N</td>
</tr>
</tbody>
</table>
Sugar-Sweetened Soft Drinks and Type 2 Diabetes, NHS2 1991-1998

Sugar-sweetened soft drink consumption

Relative Risk

P<0.001 for trend

Sugar-sweetened soft drink consumption

<1/mo 1-4/mo 2-6/wk >=1/d

1.00 1.06 1.11 1.50

1.00 1.39 1.85

1.41

multivariate adjusted multivariate + BMI

Schulze et al. JAMA 2004
Forrest Plot of Studies Evaluating SSB intake and Risk of Metabolic Syndrome

Fixed-effects estimate: RR 1.17 (1.09, 1.26)

N = 19,431
5,803 cases

Malik et al. 2010. Diabetes Care. 33:2477-2483
Drinking caloric beverages increases the risk of adverse cardiometabolic outcomes in the Coronary Artery Risk Development in Young Adults (CARDIA) Study. N= 2774, 20 yr follow-up

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>RR (95% CI)</th>
<th>P trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>High WC</td>
<td>1.09 (1.04, 1.15)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>High Fasting glucose</td>
<td>1.03 (0.95, 1.12)</td>
<td>0.4600</td>
</tr>
<tr>
<td>High TG</td>
<td>1.06 (1.01, 1.13)</td>
<td>0.033</td>
</tr>
<tr>
<td>High LDL</td>
<td>1.18 (1.02, 1.36)</td>
<td>0.018</td>
</tr>
<tr>
<td>Low HDL</td>
<td>1.06 (0.97, 1.16)</td>
<td>0.192</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.06 (1.01, 1.12)</td>
<td>0.023</td>
</tr>
</tbody>
</table>
Relative Risks for Incident Hypertension According to Frequency of Sugared Cola Intake

Nurses’ Health Study (1990-2002)
N = 53,175

N = 87,369

JAMA, November 9, 2005—Vol 294, No. 18
Evidence from Short Term Trials:

- Parallel, 10 wks: Sucrose-rich diet increased postprandial glucose, insulin, and lipids compared artificial sweeteners in overweight healthy subjects. *Food Nutr Res 2011;55.*

- Parallel, 10-wks: Sucrose-rich diet increased serum levels of haptoglobin, transferrin and CRP compared artificial sweetener in overweight healthy subjects. *Am J Clin Nutr 2005;82(2):421-7*

Sweetened beverage consumption and risk of coronary heart disease in women

Teresa T Fung, Vasanti Malik, Kathryn M Rexrode, JoAnn E Manson, Walter C Willett, and Frank B Hu

### TABLE 3
Multivariate relative risks (RRs) for a 2-serving increase in specific sugar-sweetened beverage consumption and risk of coronary heart disease (n = 88,520)

<table>
<thead>
<tr>
<th>Beverage type</th>
<th>RR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sugar-sweetened beverages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariate-adjusted</td>
<td>1.32 (1.17, 1.48)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Multivariate-adjusted + diet</td>
<td>1.28 (1.14, 1.44)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Colas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariate-adjusted</td>
<td>1.40 (1.21, 1.63)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Multivariate-adjusted + diet</td>
<td>1.35 (1.15, 1.57)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Carbonated noncola</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariate-adjusted</td>
<td>1.33 (0.91, 1.94)</td>
<td>0.24</td>
</tr>
<tr>
<td>Multivariate-adjusted + diet</td>
<td>1.27 (0.87, 1.86)</td>
<td>0.22</td>
</tr>
<tr>
<td>Fruit drinks and punch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariate-adjusted</td>
<td>1.32 (1.02, 1.70)</td>
<td>0.04</td>
</tr>
<tr>
<td>Multivariate-adjusted + diet</td>
<td>1.33 (1.03, 1.71)</td>
<td>0.03</td>
</tr>
</tbody>
</table>
SSB and risk of CHD in men (N=42,883) Followed for over 22 years

<table>
<thead>
<tr>
<th></th>
<th>RR 1 serv/d</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total SSB</td>
<td>1.19 (1.11, 1.28)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Cola</td>
<td>1.19 (1.09, 1.31)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Non-cola</td>
<td>1.25 (1.04, 1.51)</td>
<td>0.02</td>
</tr>
<tr>
<td>Fruit drinks</td>
<td>1.25 (1.08, 1.46)</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

SSB associated with increased: triglycerides, CRP, IL6, TNFr1, TNFr2,

SSB associated with decreased: HDL, Lp(a), and leptin

(p values < 0.02).

Multi-variable adjusted models

Circulation. 2012;125:1735-1741
Potential biological mechanisms underlying the effect of SSBs on weight gain, and cardiometabolic disease risk

Malik et al. *Circulation.* 2010; 121: 1356-1364
Fructose and Uric acid

Fructose

ATP

Fructose-1-phosphate

Triglycerides

↓ Phosphate

ADP ➔ AMP

↑AMP deaminase

Uric acid

Hallfrisch J. et al, FASB J, 1990

Uric acid may increase blood pressure by development of renal disease, endothelial dysfunction and activation of the rennin-angiotensin system.
Strength of the Epidemiologic Evidence

• Weight gain and obesity
  ***
• Type 2 diabetes and metabolic syndrome
  ***
• Hypertension, inflammation, dyslipidemia
  **
• CHD
  *
**Bradford Hill Criteria for Causality Applied to Evidence Evaluating SSB Consumption and Risk of Type 2 Diabetes**

<table>
<thead>
<tr>
<th>Bradford Hill Criteria</th>
<th>SSB and Risk of Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Strength of Association</td>
<td>✔ RR: 1.26 (1.12, 1.41) for 1-2 servings/day compared to &lt; 1/mo, from meta-analysis</td>
</tr>
<tr>
<td>2) Consistency</td>
<td>✔ Consistent data from large prospective cohort studies</td>
</tr>
<tr>
<td>3) Specificity</td>
<td>--- SSB increase risk of related metabolic conditions and unrelated conditions such as dental caries</td>
</tr>
<tr>
<td>4) Temporality</td>
<td>✔ Prospective studies have established temporality</td>
</tr>
<tr>
<td>5) Biological Gradient</td>
<td>✔ Increase 1 SSB/d associated with 15% increased risk RR: 1.15 (1.11, 1.20), from meta-analysis</td>
</tr>
<tr>
<td>6) Biological Plausibility</td>
<td>✔ Incomplete compensation for liquid calories; glycemic effects; metabolic effects of fructose</td>
</tr>
<tr>
<td>7) Experimental Evidence</td>
<td>✔ Experimental evidence from studies of risk factors</td>
</tr>
</tbody>
</table>

“Biological coherence” and “Analogy” omitted

Over a 10-year period US $82 billion in medical costs was attributable to excess SSB consumption (defined as one beverage per week). Wang et al HEALTH AFFAIRS 31, NO. 1 (2012): 199–207
ARE YOU POURING ON THE POUNDS?

DON'T DRINK YOURSELF FAT.
Cut back on soda and other sugary beverages.
Go with water, seltzer or low-fat milk instead.

NEW YORK CITY DEPARTMENT of HEALTH and MENTAL HYGIENE
SSBs provide little nutritional value and have also been linked to:

- gallstone disease
- hyperuricemia
- gout
- kidney disease
- fatty liver
- decreased bone mineral density
- dental carries
Healthy Alternatives?

- Diet Cola
- Grapefruit
- Coffee
- Water
- Green Tea

- 17%
Bottom Line:

Limiting intake of SSB’s is one simple change that if implemented could have a measurable impact on weight control and risk of diabetes and other metabolic diseases in the general population.
Thank You!
Relative risk of type 2 diabetes associated with replacement of various beverages
AHA recommends no more than 100 kcal (5% energy) for women and 150 kcal (7.5% energy) for men from added sugar.
Forrest plot of studies evaluating SSB consumption and adiposity in children, per change in BMI units for each 12-oz serving per day change in SSB (random-effects)

**Study**
- Ludwig, 2001
- Berkey Boys, 2004
- Berkey Girls, 2004
- James, 2004
- Newby, 2004
- Phillips, 2004
- Blum, 2005
- Ebbeling, 2006
- Mundt Boys, 2006
- Mundt Girls, 2006
- Striegel-Moore, 2006

**% Weight**
- Ludwig, 2001: 8.09
- Berkey Boys, 2004: 18.93
- Berkey Girls, 2004: 19.43
- James, 2004: 3.20
- Newby, 2004: 0.64
- Phillips, 2004: 8.01
- Blum, 2005: 2.94
- Ebbeling, 2006: 0.82
- Mundt Boys, 2006: 12.49
- Mundt Girls, 2006: 7.83
- Striegel-Moore, 2006: 17.63

**Combined**: 0.03 (-0.00, 0.07)

**Fixed Effects**: 0.03 (0.01, 0.04)

Potential mechanisms

Reduced compensation for energy from liquids?

Mean reported energy intake prior to and after both intervention periods N=15, cross-over

(Source: Di Meglio CP & Mattes RD, Int J Obes Relat Metab Disord 2000;24:794-800)
Frequent and high changes in blood glucose are thought to be risk factors for diabetes.

**Glycemic index (GI):**

\[
\text{GI} = \frac{\text{AUC}}{\text{AUC}_{\text{ref}}} \times 100
\]


**Serving size**

<table>
<thead>
<tr>
<th>Food</th>
<th>Glycemic index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke 250 mL</td>
<td>63</td>
</tr>
<tr>
<td>Mashed potato 1 cup</td>
<td>74</td>
</tr>
<tr>
<td>White bread 1 slice</td>
<td>70</td>
</tr>
<tr>
<td>Sugar, table 1 tsp</td>
<td>68</td>
</tr>
<tr>
<td>Carrots 0.5 cup</td>
<td>47</td>
</tr>
<tr>
<td>Pasta 1 cup</td>
<td>42</td>
</tr>
</tbody>
</table>

Glycemic load

Glycemic index does not take into account total carbohydrate

Glycemic load:
GI * carb / 100

<table>
<thead>
<tr>
<th>Serving size</th>
<th>Glycemic index</th>
<th>Carbohydrate (g)</th>
<th>Glycemic load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke 250mL</td>
<td>63</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Mashed potato 1 cup</td>
<td>74</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>White bread 1 slice</td>
<td>70</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Sugar, table 1 tsp</td>
<td>68</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Carrots 0.5 cup</td>
<td>47</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Pasta 1 cup</td>
<td>42</td>
<td>47</td>
<td>20</td>
</tr>
</tbody>
</table>

GL ≤ 10 = low
GL ≥ 20 = high
Potential mechanisms

Postprandial insulin response and satiety

Lowering of blood glucose in response to the spike in insulin triggers a hormonal cascade leading to increased appetite.

(Source: Ludwig, Jama 2002;287:2414-2423)
Hepatic Fructose Metabolism

Lim, J. S. et al. (2010) The role of fructose in the pathogenesis of NAFLD and the metabolic syndrome
Nat. Rev. Gastroenterol. Hepatol. doi:10.1038/nrgastro.2010.41
Banning All Sugar-Sweetened Beverages in Middle Schools

Public schools in 40 states

Reduction of In-School Access and Purchasing but Not Overall Consumption

Daniel R. Taber, PhD, MPH; Jamie F. Chriqui, PhD, MHS; Lisa M. Powell, PhD; Frank J. Chaloupka, PhD

Figure. Prevalence of sugar-sweetened beverage (SSB) access within school, purchasing in school within the past week, and consumption anywhere within the past week, by state policy governing beverages sold in middle schools.