

# The Sugar “Maize”: Sugar, High Fructose Corn Syrup, Obesity and Metabolic Risk: From Genes to Policy

Michael I Goran, PhD

Professor of Preventive Medicine; Physiology & Biophysics;  
and Pediatrics

Director, Childhood Obesity Research Center  
Co-Director, Diabetes & Obesity Research Institute  
Keck School of Medicine, USC



# Brief History of Sugar (sucrose)

- 8,000 BC - first domestication of sugar cane
- 400 BC - first written mention of sugar in Indian literature referring to use in sweet puddings and drinks
- 500 AD - evidence of sugar making in India
- 400-800 AD - major production of sugar spreads west from India across the Persian Gulf to Arab countries
- 1000 AD - sugar spread to Europe through the Arab conquest
- 1200 - medicinal use of sugar

# Brief History of Sugar (sucrose)

- 16th century - production centered in the Mediterranean and Atlantic Islands
- 1650 - Major sugar consumption among English nobility and wealthy
- 1800 - sugar has become a necessity of the diet
- 1900 - sugar supplies 20% of calories in the English diet
- 1957 - development of high fructose corn syrup
- 1970 onwards - proliferation of HFCS and sugar in the diet correlated with increases in obesity



**\$10 BILLION IS SPENT ANNUALLY ADVERTISING  
FOOD AND BEVERAGES TO CHILDREN; \$500  
MILLION ON SUGARY BEVERAGES**

IOM, 2005

FTC, 2008

**17 teaspoons**

Amount of sugar in a 20-oz serving

**41 percent**

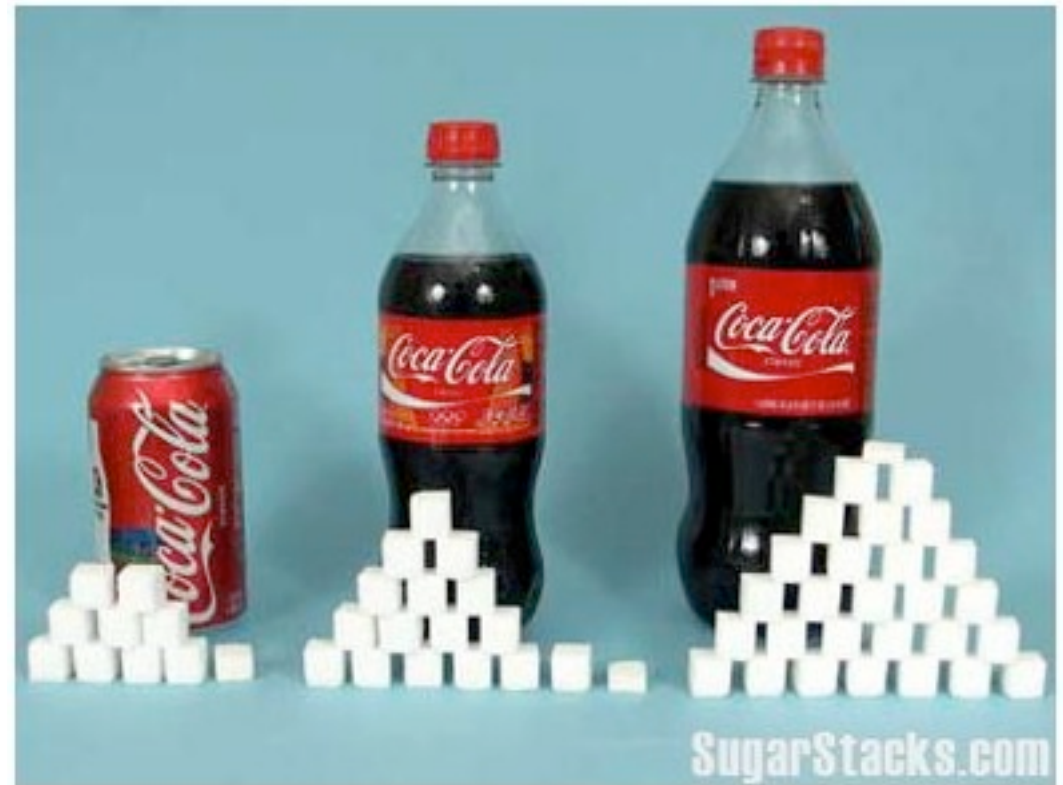
Kids age 2-11 that drink at least 1 soda per day

**62 percent**

Kids aged 12-17 who drink at least 1 soda per day

**39 pounds**

Amount of sugar consumed in 1 year from 1 soda per day





venti frappuccino with  
whipped cream  
89g sugars  
(17 teaspoons)



US sugar consumption  
= 70kg/person/year

if you stacked all the  
sugar as cubes from 1  
day of sugar  
consumption in the US it  
would tower half way to  
the moon

# Legislation - Soda Tax?



The NEW ENGLAND  
JOURNAL of MEDICINE

[FREE NEJM E-TOC](#) | [HOME](#) | [SUBSCRIBE](#) | [CURRENT ISSUE](#) | [PAST ISSUES](#) | [COLLECTIONS](#) |

[Sign in](#) | [Get NEJM's E-Mail Table of Contents — Free](#) | [Subscribe](#)

PERSPECTIVE

Volume 360:1805-1808    April 30, 2009    Number 18

[Next](#) ▶

## Ounces of Prevention — The Public Policy Case for Taxes on Sugared Beverages

*Kelly D. Brownell, Ph.D., and Thomas R. Frieden, M.D., M.P.H.*

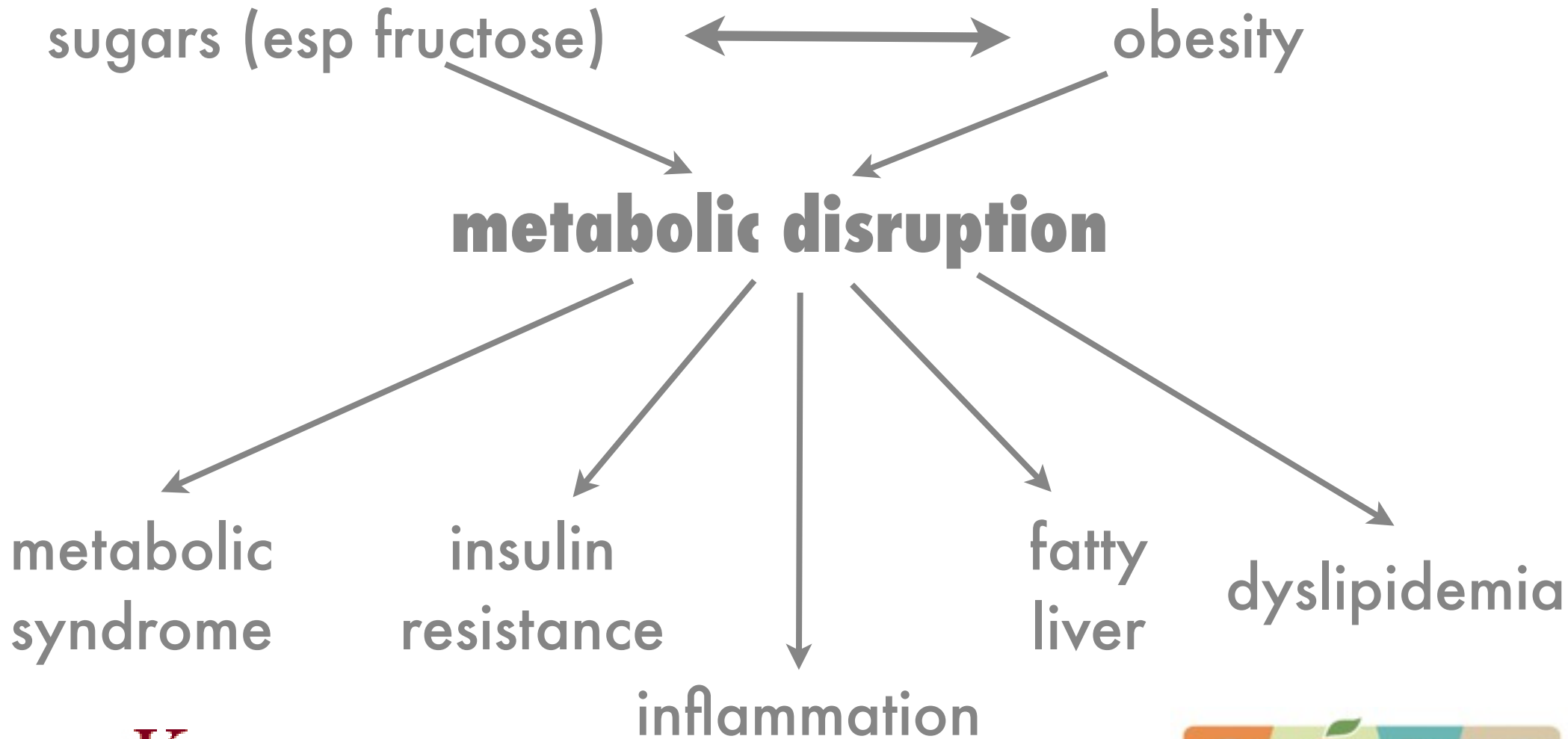
A couple of local ballot measures in the US have failed  
The beverage industry has lobbied hard against them

One study has projected that even a 20% tax on sodas would only lead to a long-term weight loss of 3 pounds



# mechanisms

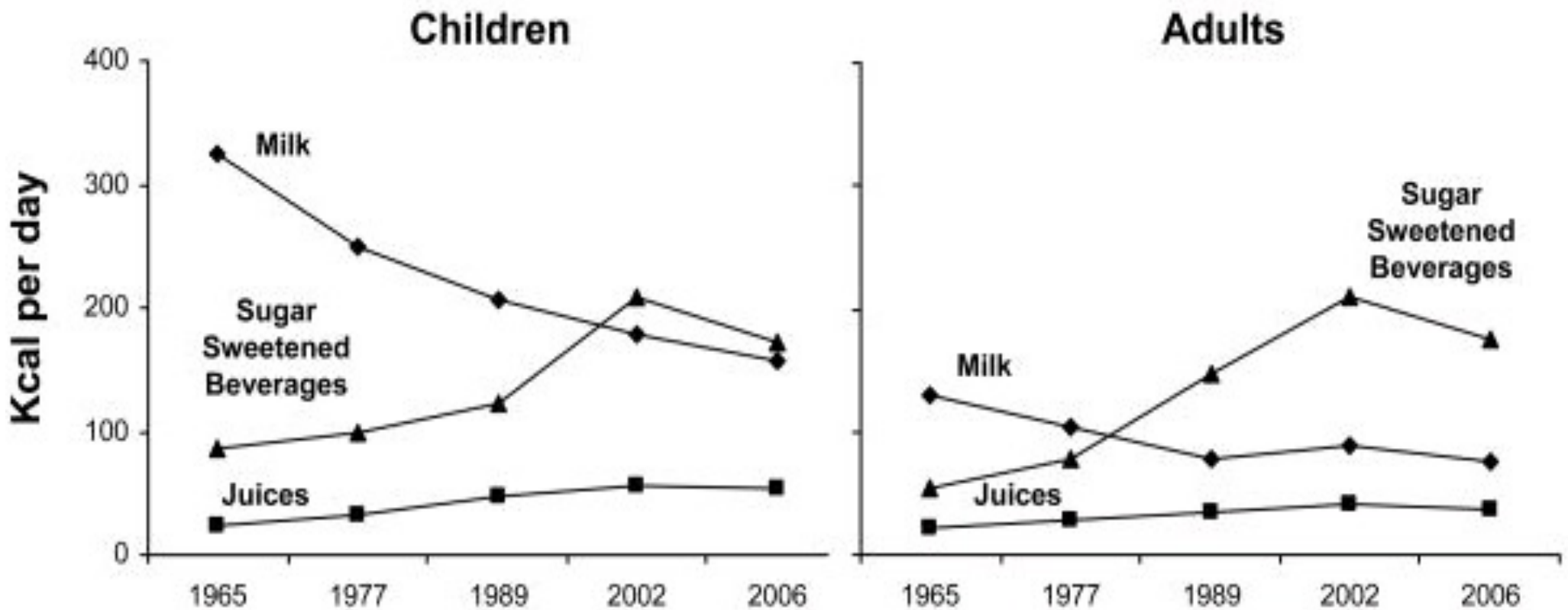
# Mechanisms Linking Increased Sugar to Negative Health Outcomes: The Double Edged Sword



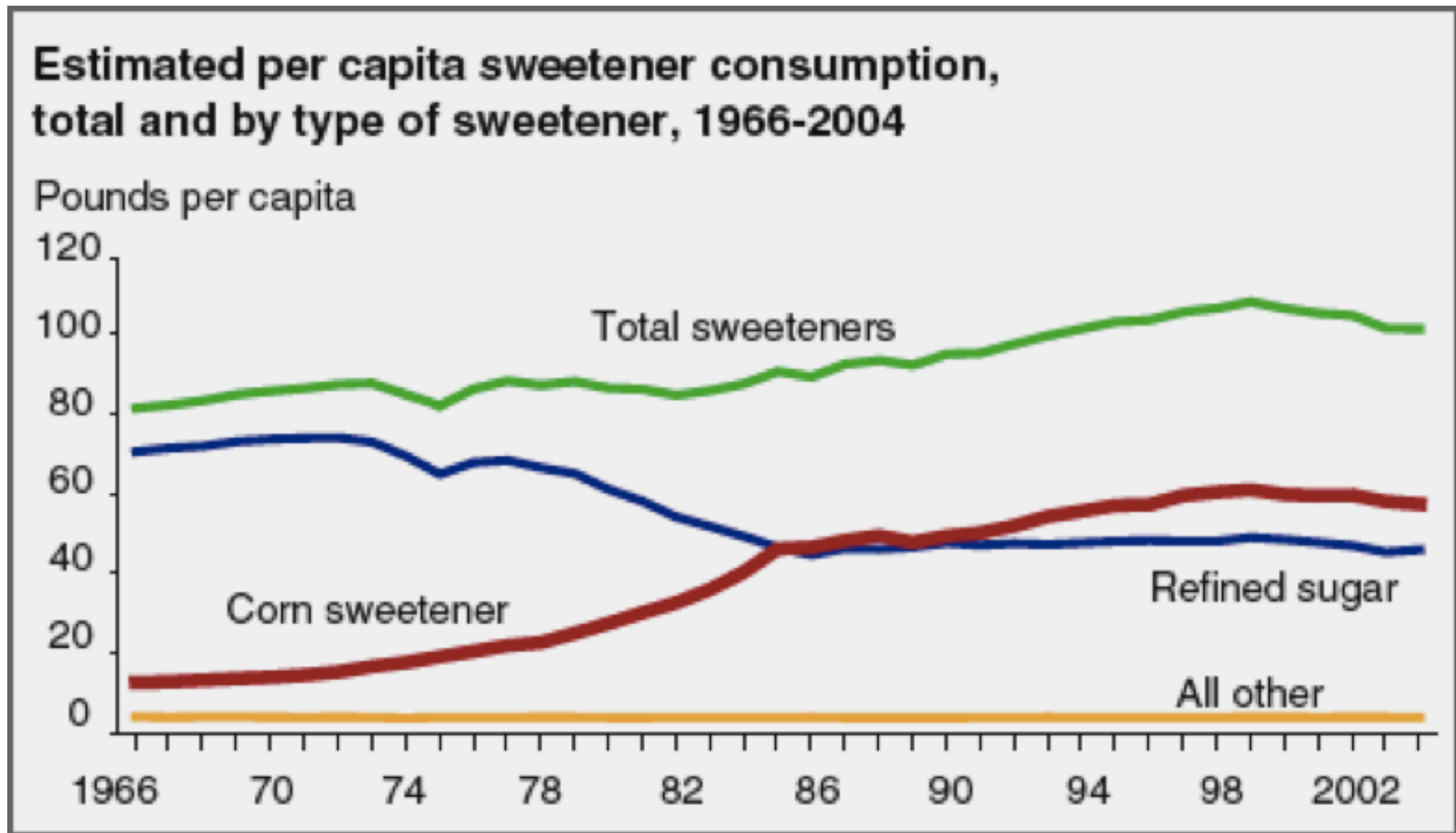
# why has high sugar become such an important issue in terms of obesity and metabolic outcomes?

1. trends in food and beverage consumption; related to economics
2. advent and proliferation of high fructose corn syrup
3. exacerbation of effects of sugars on metabolism in the obese state
4. earlier introduction of fructose in the diet from sugar (glucose + fructose) relative to breastfeeding (lactose = glucose+galactose)

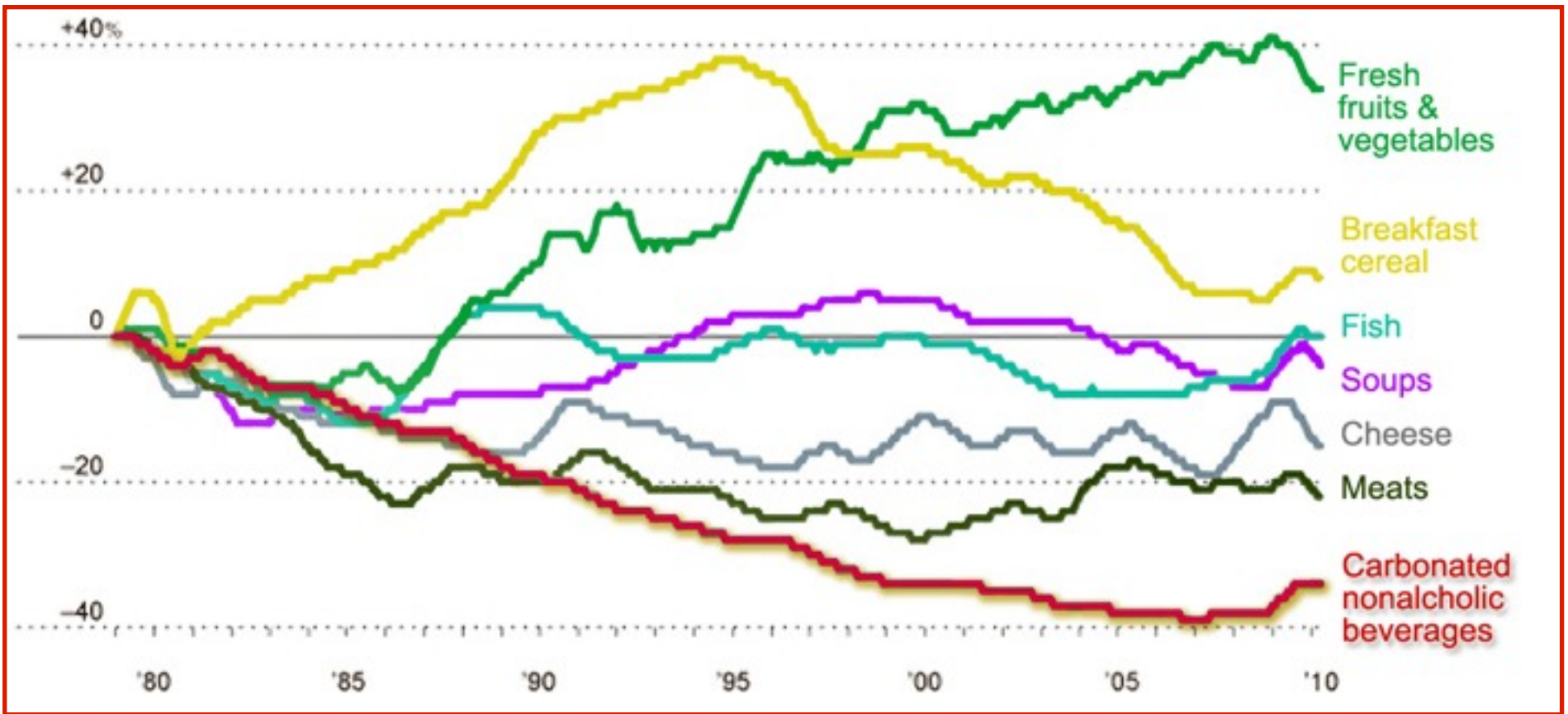
# Per Capita US Trends in Calories from Beverages



# advent of High Fructose Corn Syrup: different from sugar



# Consumer Price Index - Sodas are a good deal





10 teaspoons  
sugar

27 teaspoons  
sugar

**6.5 oz  
(1920s)**

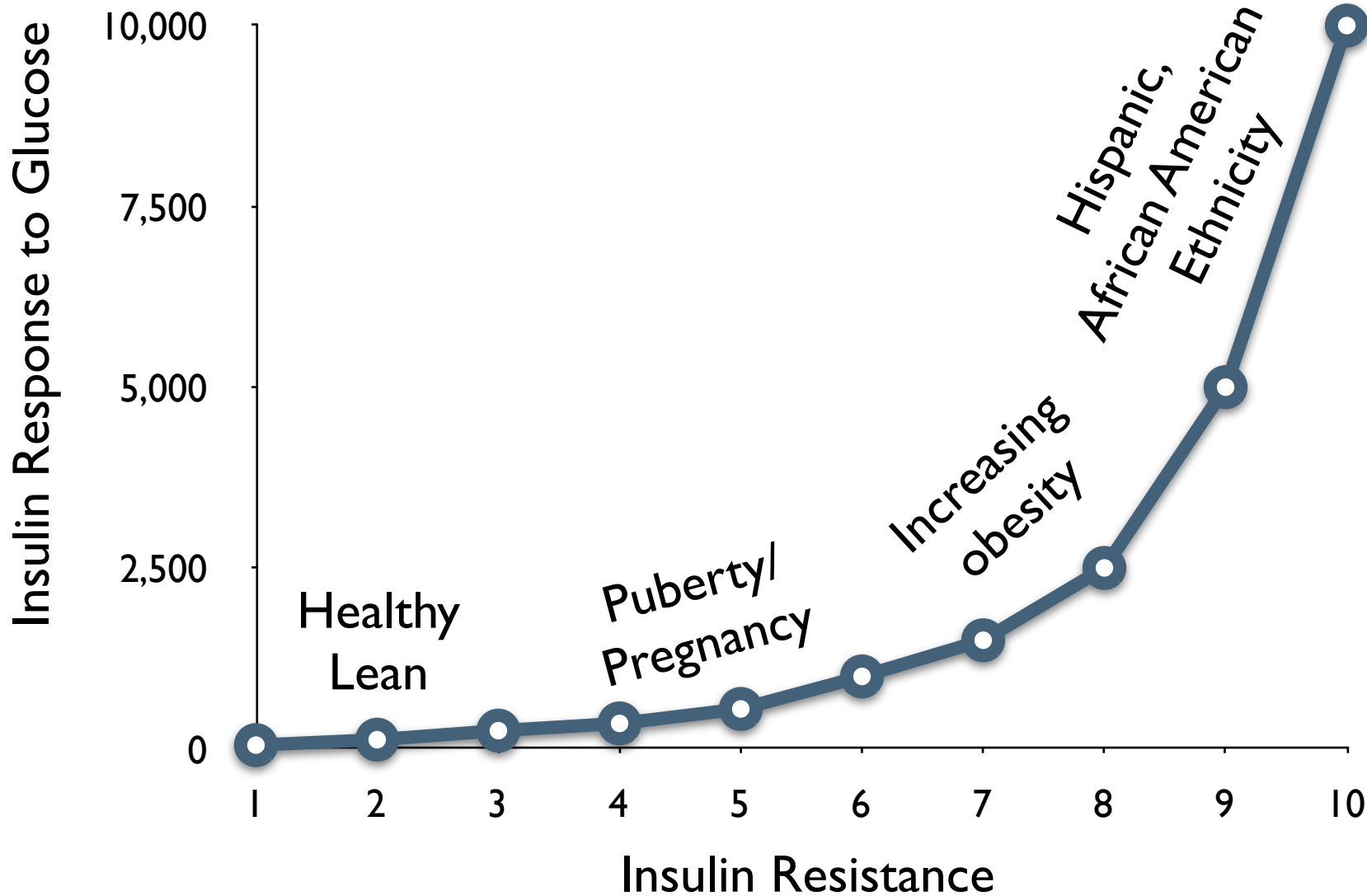
**12 oz  
(1960s)**

**20 oz  
(1990s)**

**33 oz (1L)  
Today**

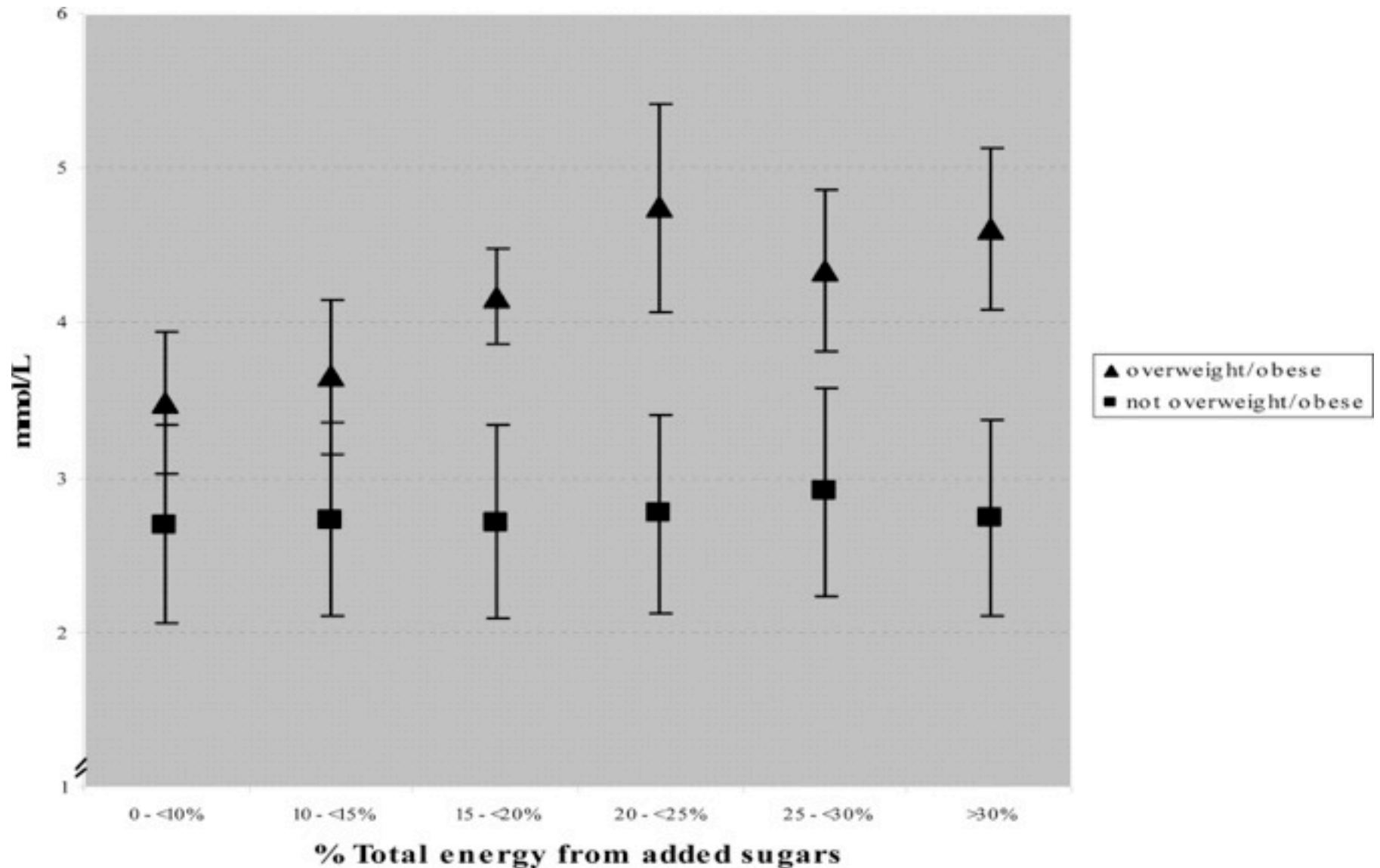






As you become more obese and insulin resistant the demand on beta-cells to secrete insulin in response to glucose, rises exponentially

# Adjusted HOMA-IR by Intake of Added Sugars in US Adolescents



Welsh J A et al. *Circulation* 2011;123:249-257

Copyright © American Heart Association

# Sugar and obesity: the evidence

# Sugar Sweetened Beverages and Obesity in Children: Key Prospective Studies

- Ludwig et al Lancet 2001, 357:505-8
  - 19 month study of 548 middle school students
  - Every additional serving of per day increased risk of obesity by 60%
- Walsh et al. Pediatrics 2005, 115:223
  - 1 year study of 10,904 children ages 2 to 3 years
  - Children were 2-times more likely to become or remain overweight if they drank sugar-sweetened beverages

# Sugar Sweetened Beverages and Obesity in Children: Key Intervention Studies

James et al. British Med J 2004, 328:1237

- Randomized controlled trial, 600 children 7 - 11 yr
- Educational program designed to eliminate all “fizzy drinks” (including non-nutritively sweetened)
- Consumption differed between groups by < 2 oz per day
- Incidence of overweight/obesity significantly lower in the intervention group: 0.2 vs 7.7%

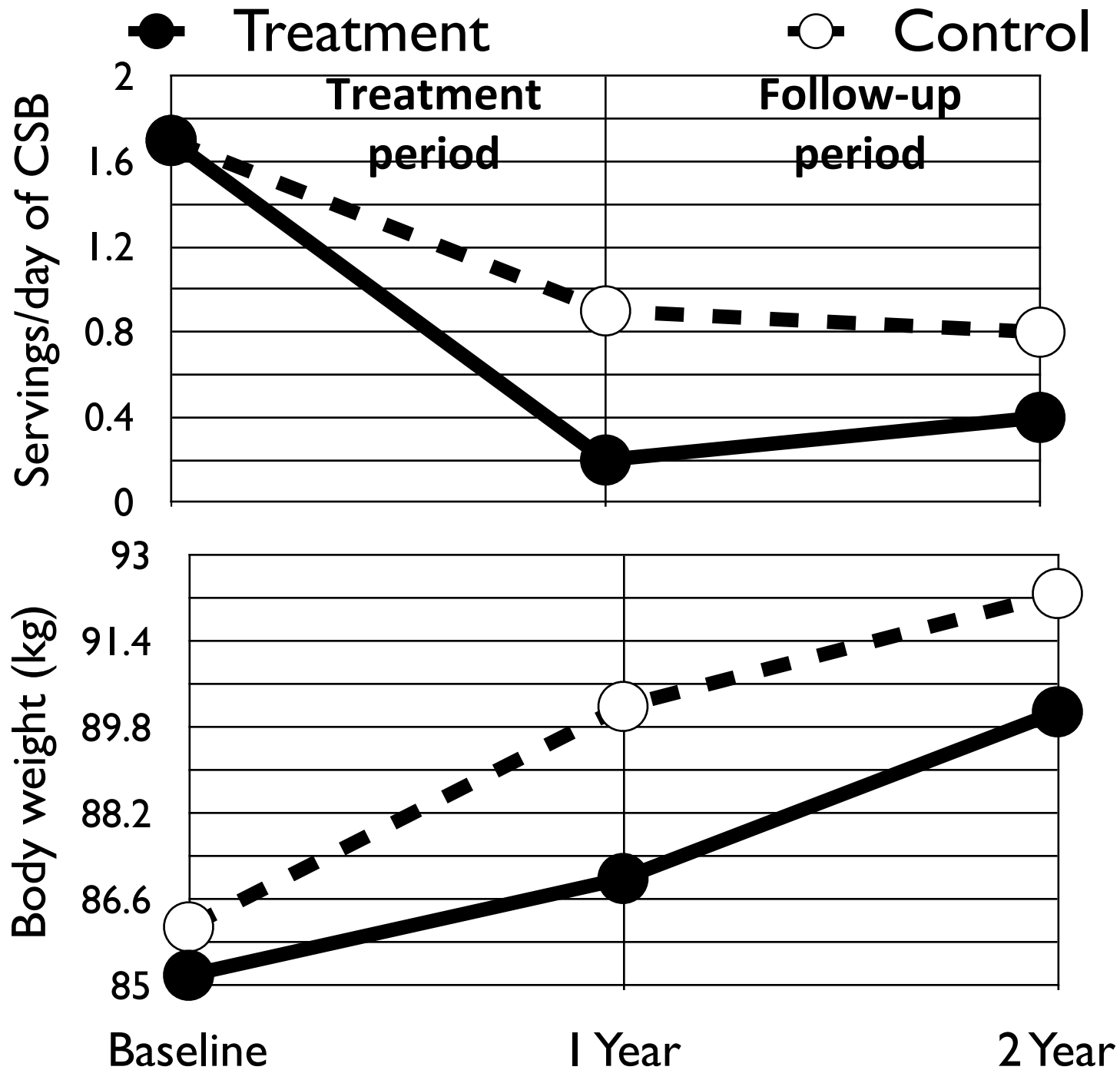
# Sugar Sweetened Beverages and Obesity in Children: Key Intervention Studies

Ebbeling, Ludwig. Pediatrics 2006, 117:673

- 6-month randomized controlled trial of 103 normal weight and overweight adolescents
- Delivery of non-sugar sweetened beverages to participants homes (to replace regular beverages)
- Sugar-sweetened beverages decreased by 82% vs no change among controls ( $p < 0.0001$ )
- Among overweight/obese participants, BMI was 0.75 BMI units less in the intervention group,  $p = 0.03$

# Ebbeling et al; NEJM 2012

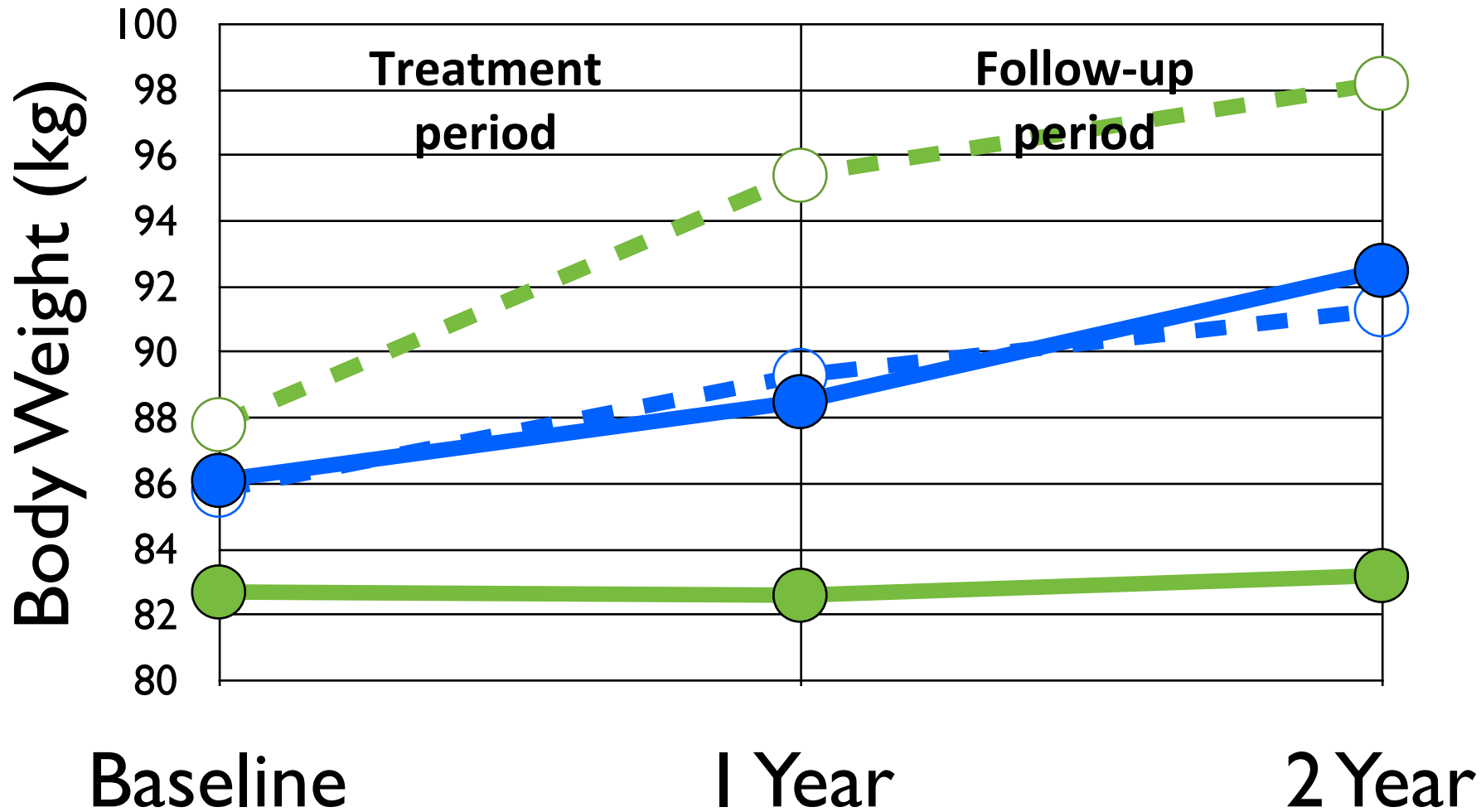
- 224 overweight & obese adolescents (mean age ~15 years)
- 1-year intervention to reduce caloric-sweetened beverages followed by 1-year follow-up
- Main outcome body weight and BMI



Small treatment effect at 1-year; not sustained after 1-Year follow-up



- Hispanic Treatment
- Non-Hispanic Treatment
- Hispanic Control
- Non-Hispanic Control

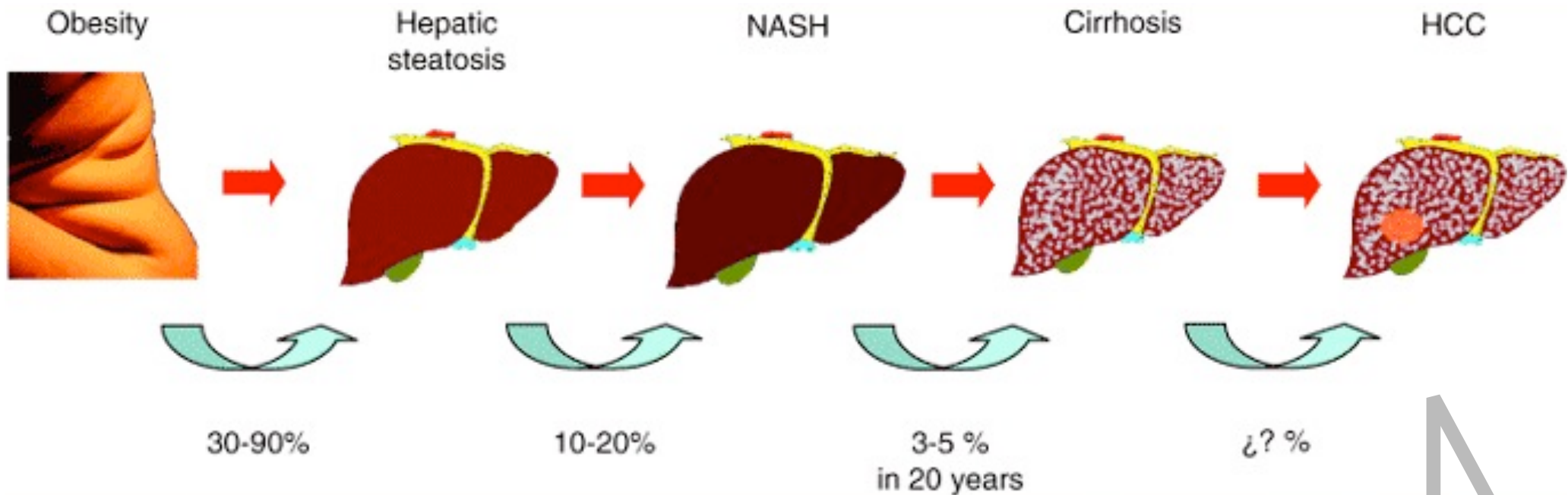


zero effect in Non-Hispanics  
 ~10kg reduced weight gain in Hispanics sustained over 2 years

Ebbeling et al, NEJM 2012

# sugar and fatty liver disease

# Spectrum of NAFLD



Diet, genes, cellular factors and food policy

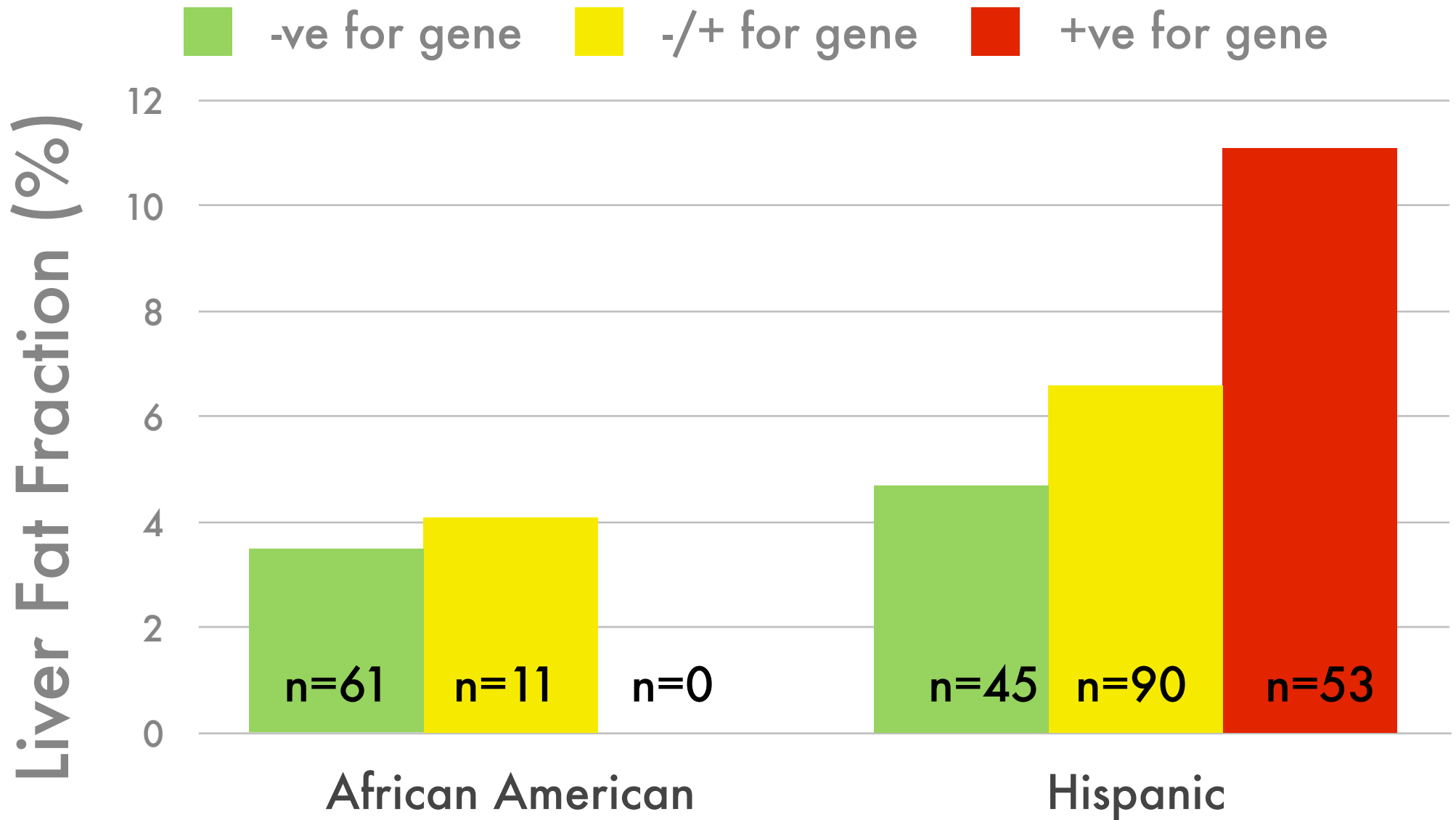
# NAFLD in Children

- Autopsy study of 742 children aged 2-19 years by Schwimmer et al 2006
- Fatty liver defined by liver fat  $>5\%$
- Overall prevalence =  $13\%$
- African American ( $1.5\%$ ); Whites ( $8.6\%$ ); Asian ( $10.2\%$ ); Hispanic ( $11.8\%$ )
- Prevalence in obese children =  $38\%$

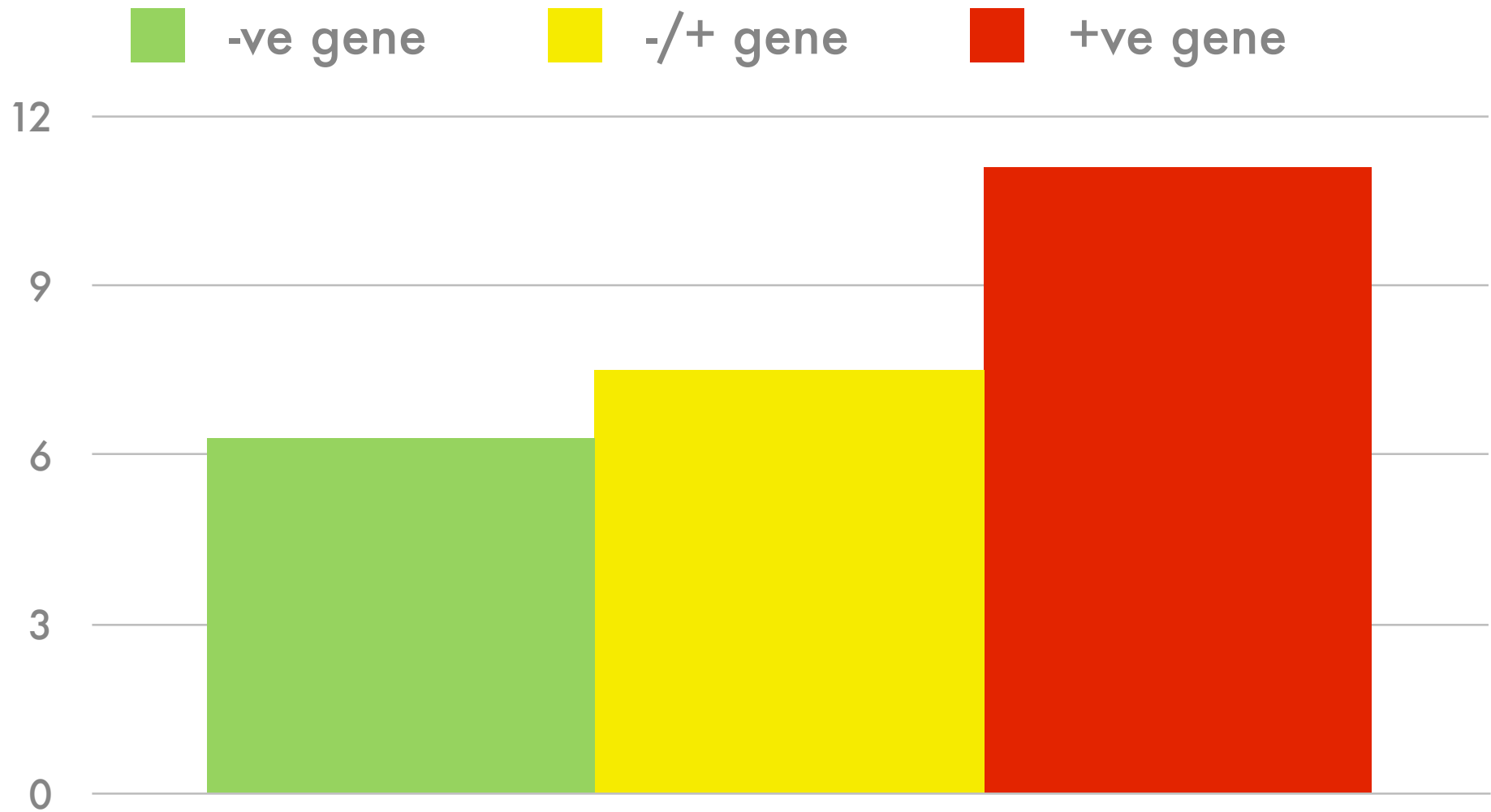
# Genetics of Fatty Liver

- A recent GWAS in adults from the Dallas Heart Study at UT Southwestern identified an amino-acid substitution (C to G) in the PNPLA3 gene associated with 2-fold higher liver fat
- Effect strongest in Hispanics in whom the frequency of the variant was much higher (49%) than African Americans (10%)
- Aim was to examine if the effect of this gene was manifested in a pediatric population

# Liver Fat Fraction by Ethnicity & Genotype

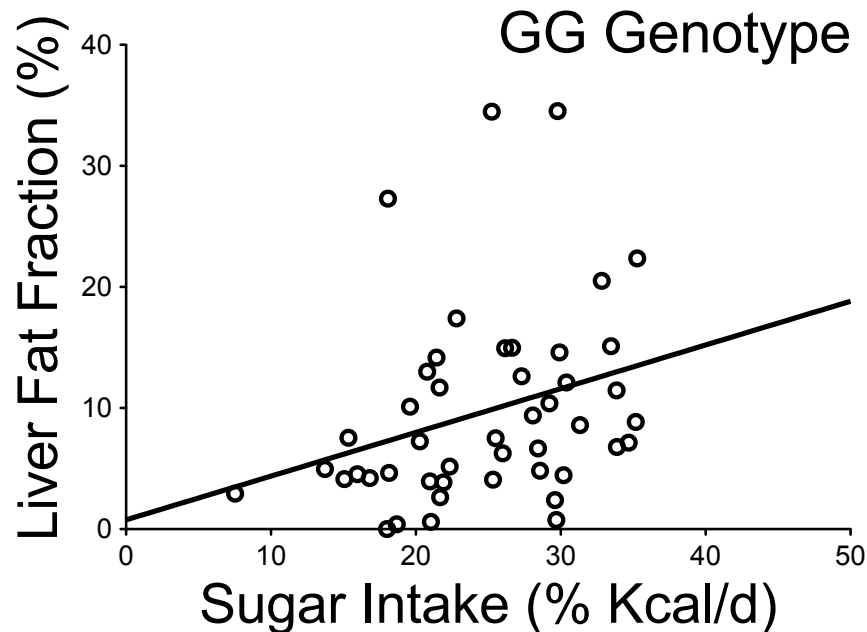
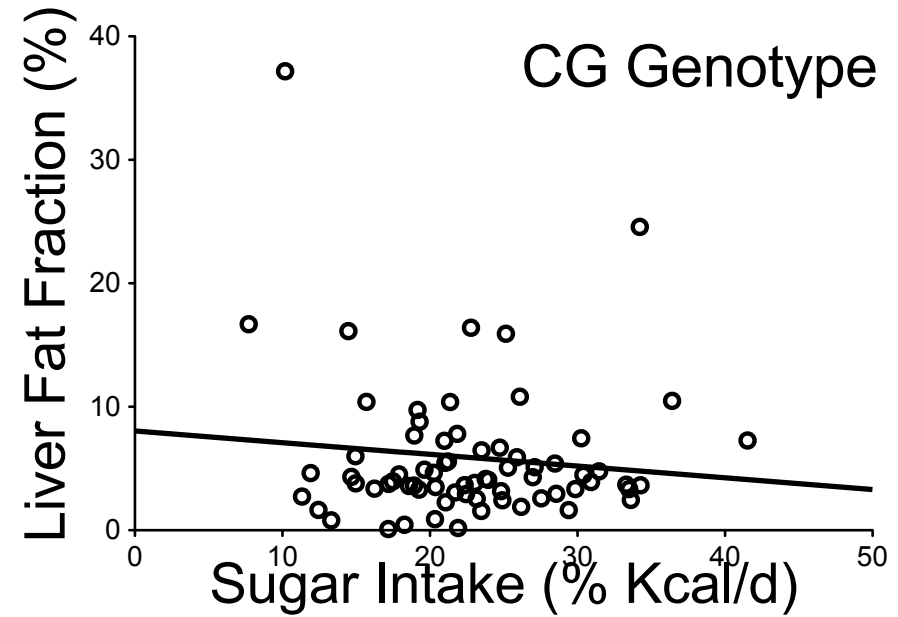
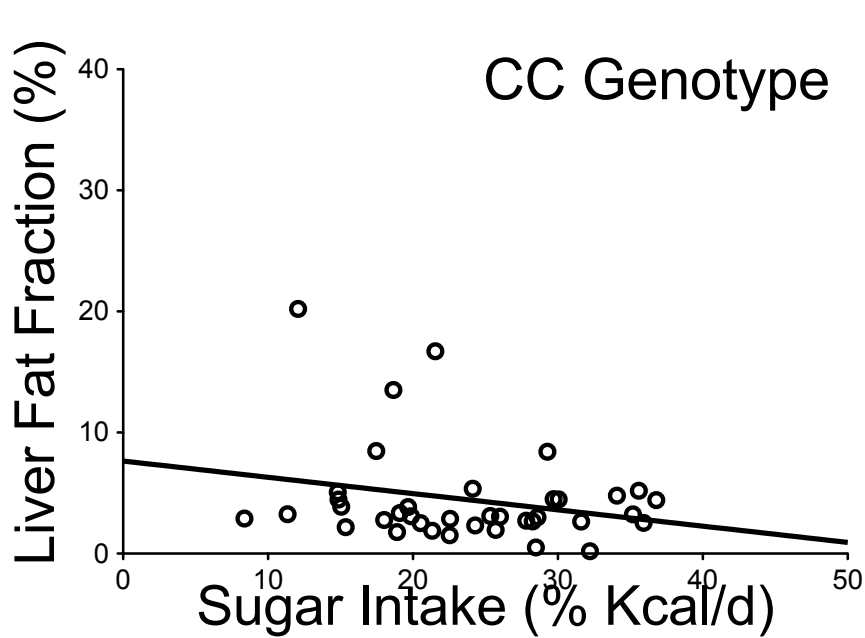


# Liver Fat Fraction in 8-10 year olds



# PNPLA3 Gene \* Diet Interaction

Davis et al, AJCN 2010





# sugar in early life

# Combined Effects of Low Breastfeeding and High Sugar Consumption

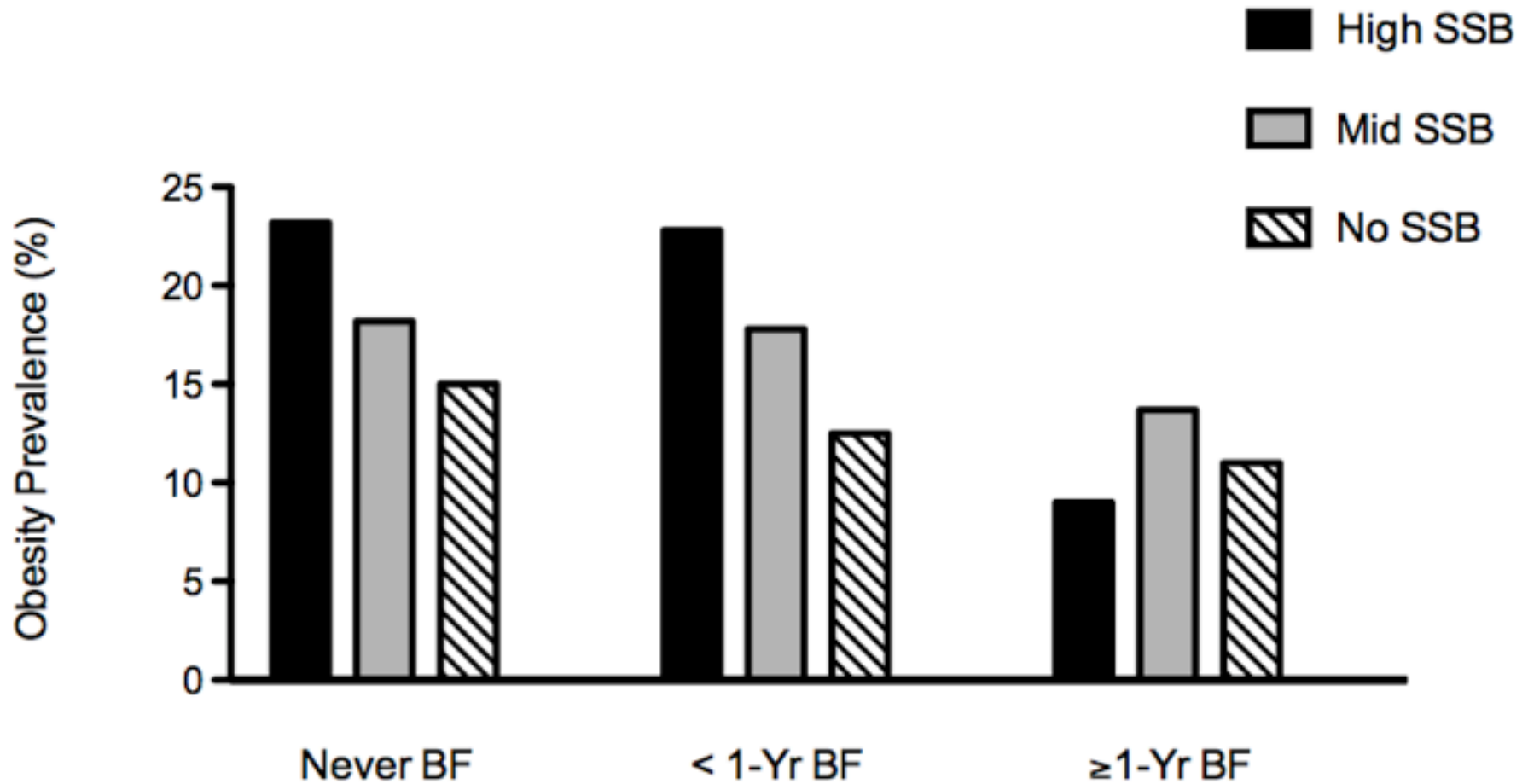
1483 Latino children (2 to 4 yrs) from WIC  
LA County

Completed early life nutrition measures on  
breastfeeding and SSB intake - 2008

height/weight/BMI data

Multinomial regressions – differences in  
prevalence of ow/ob in children between BF  
and SSB categories

# Combined Effects of Low Breastfeeding and High Sugar Consumption



# Other Animal Studies

- Sugars and especially fructose programs for obesity and metabolic risk starting with exposure in utero and during breastfeeding
- Fructose affects fat cell and hypothalamic development in ways that favor obesity

# high fructose corn syrup (HFCS)

HFCS magnifies many of the worst aspects of table sugar (sugar on steroids)

# Sucrose versus HFCS

sucrose =  $C_{12}H_{22}O_{11}$   
glucose-fructose

purified from sugar  
cane or beets

## HFCS

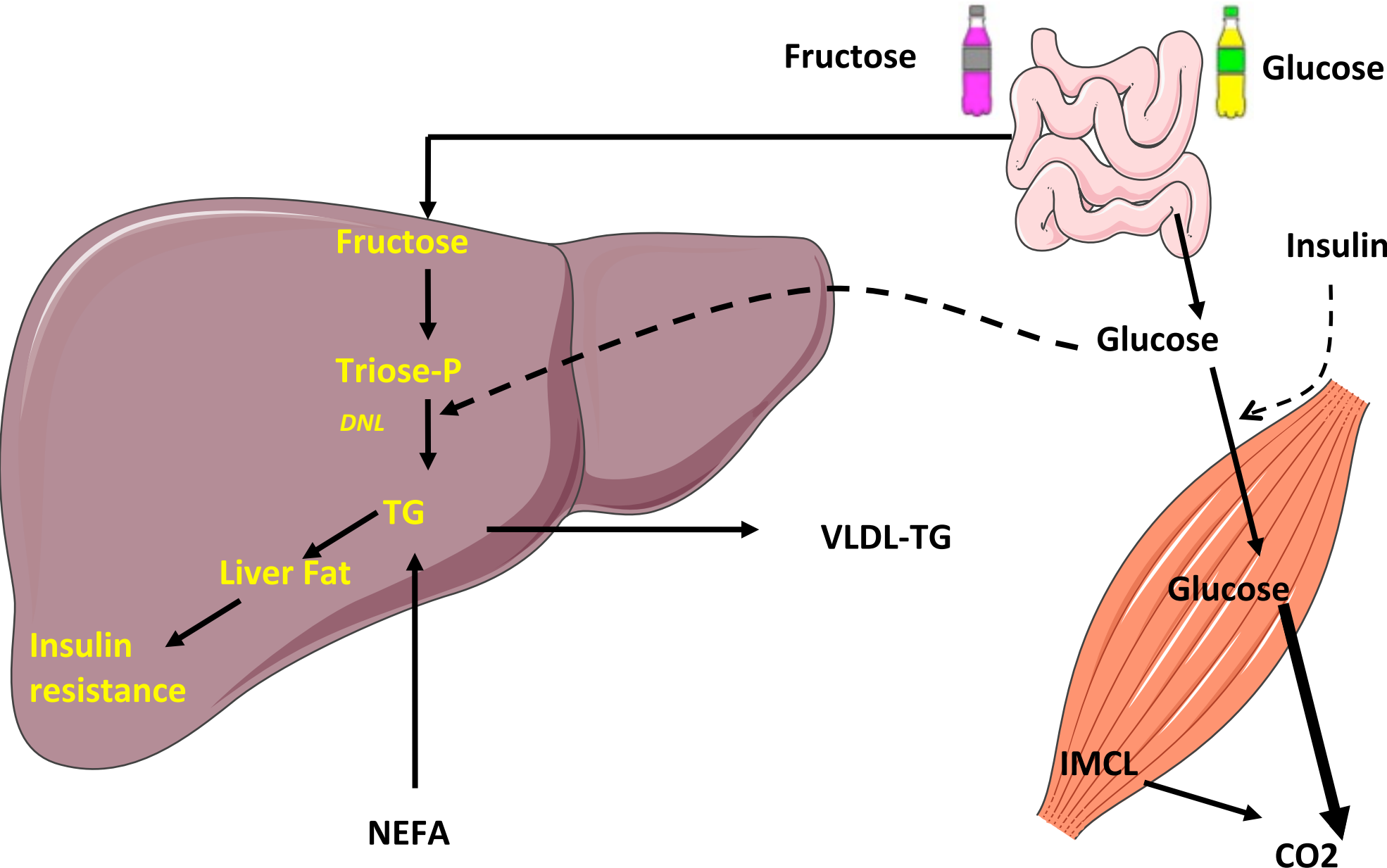
made from corn starch through  
conversion of sugars  
typically 55% fructose,  
40% glucose,  
5% other sugars;  
can be 90% fructose

advantages in food production:  
cheaper, more stable, makes food  
more appealing

# Glucose versus Fructose

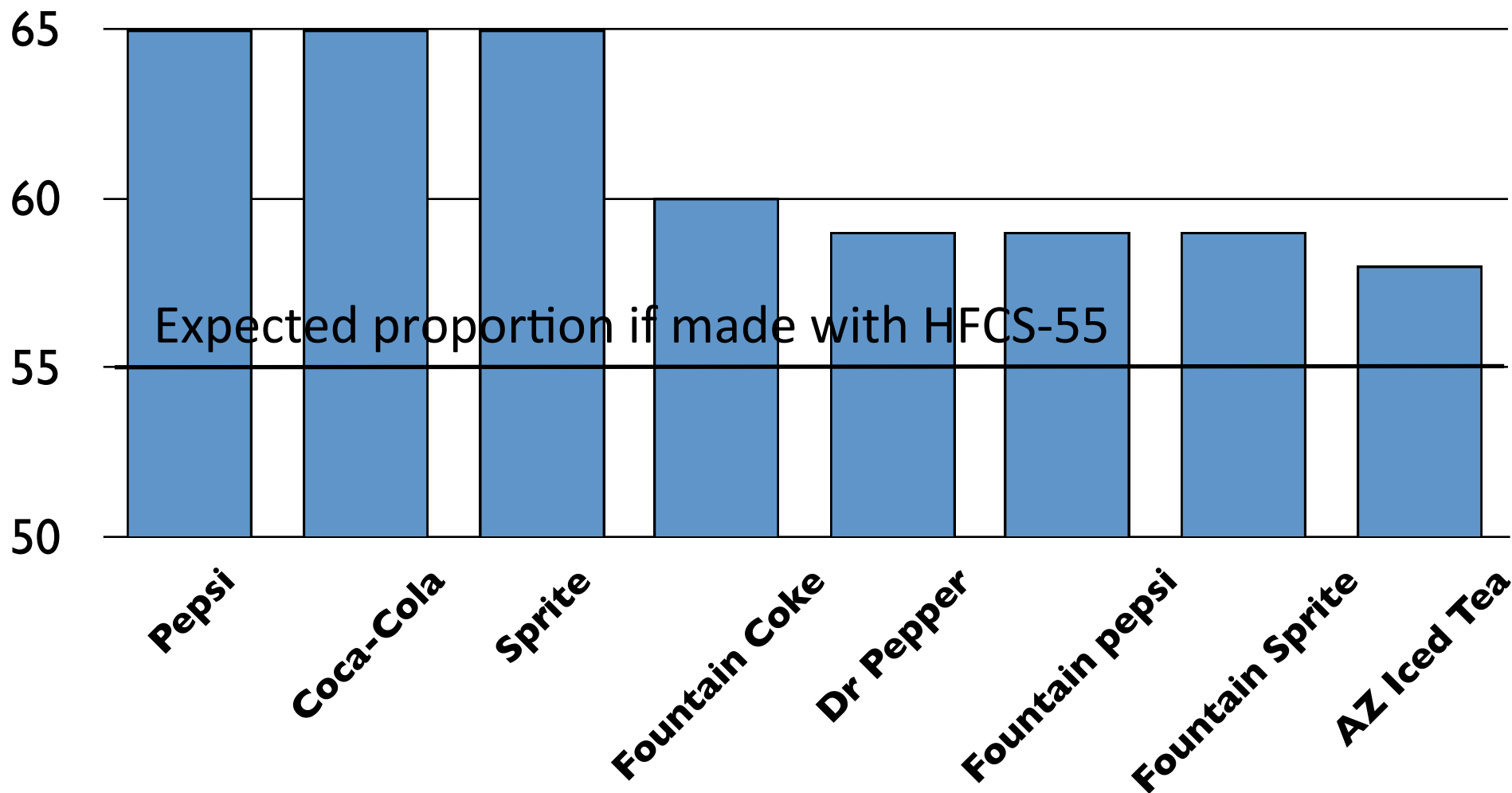
- Glucose and fructose are structurally very similar but functionally very different sugars
  - Fructose is much sweeter
  - has a specific absorption in the gut; in high doses can get fructose malabsorption with GI symptoms
  - it is metabolized almost entirely in the liver where it can be a substrate for new fat synthesis in the liver
  - does not stimulate insulin release therefore less well regulated

# Differential Effects of Fructose vs Glucose





# Fructose as a % of Sugars in Popular Drinks



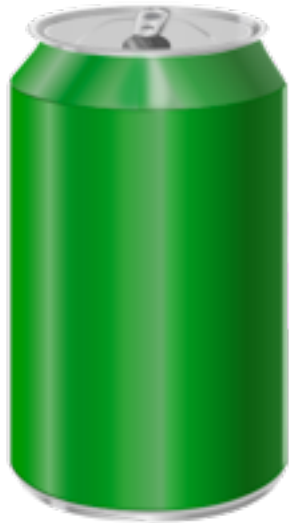
Suggests HFCS is 65:35

Fructose intake ~18% higher than assumed from label  
and 30% higher than soda made with sucrose

# Other Sugars

- Agave - mostly all fructose
- Fructose itself being used as a sweetener now in many yoghurts
- “Fruit sugar” on a label probably means fructose
- Juices from fruit probably very high in fructose and likely to have a higher fructose load than a soda made with HFCS

# Fructose versus Glucose in Foods



50g sugar

25g fructose/25g glucose (sucrose)

28g fructose/22g glucose (HFCS 55)

33g fructose/17g glucose (HFCS 65)



15g Fructose

+

other dietary benefits  
fiber, antioxidants

## **Implication:**

fructose consumption might be higher than we think and contributing to obesity and obesity complications like NAFLD

## **Policy Implication:**

Need better label information on fructose content of foods and beverages

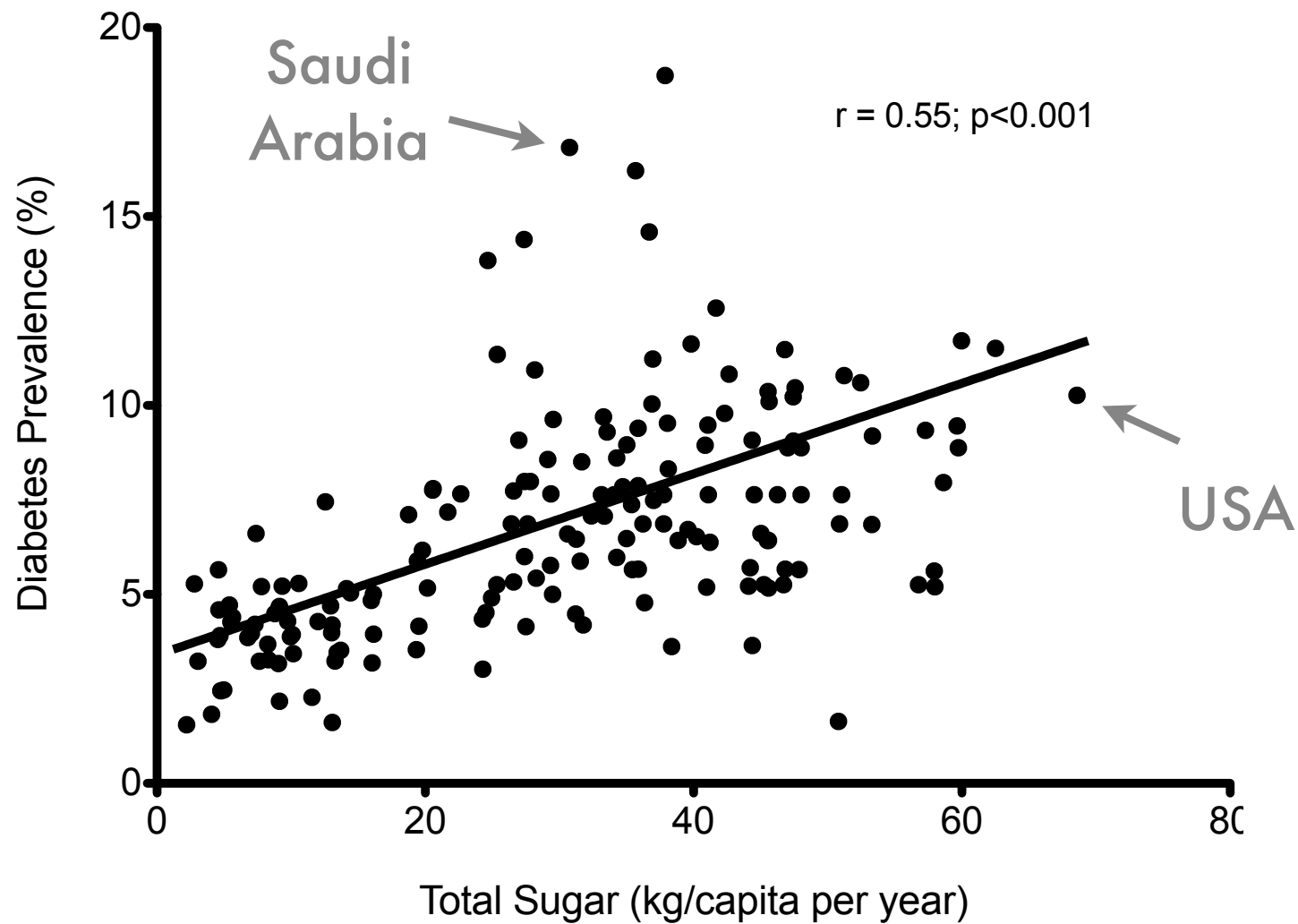
# Global Influence of Dietary Sugar & HFCS on Obesity & Diabetes

Goran et al  
Global Public Health, 2012

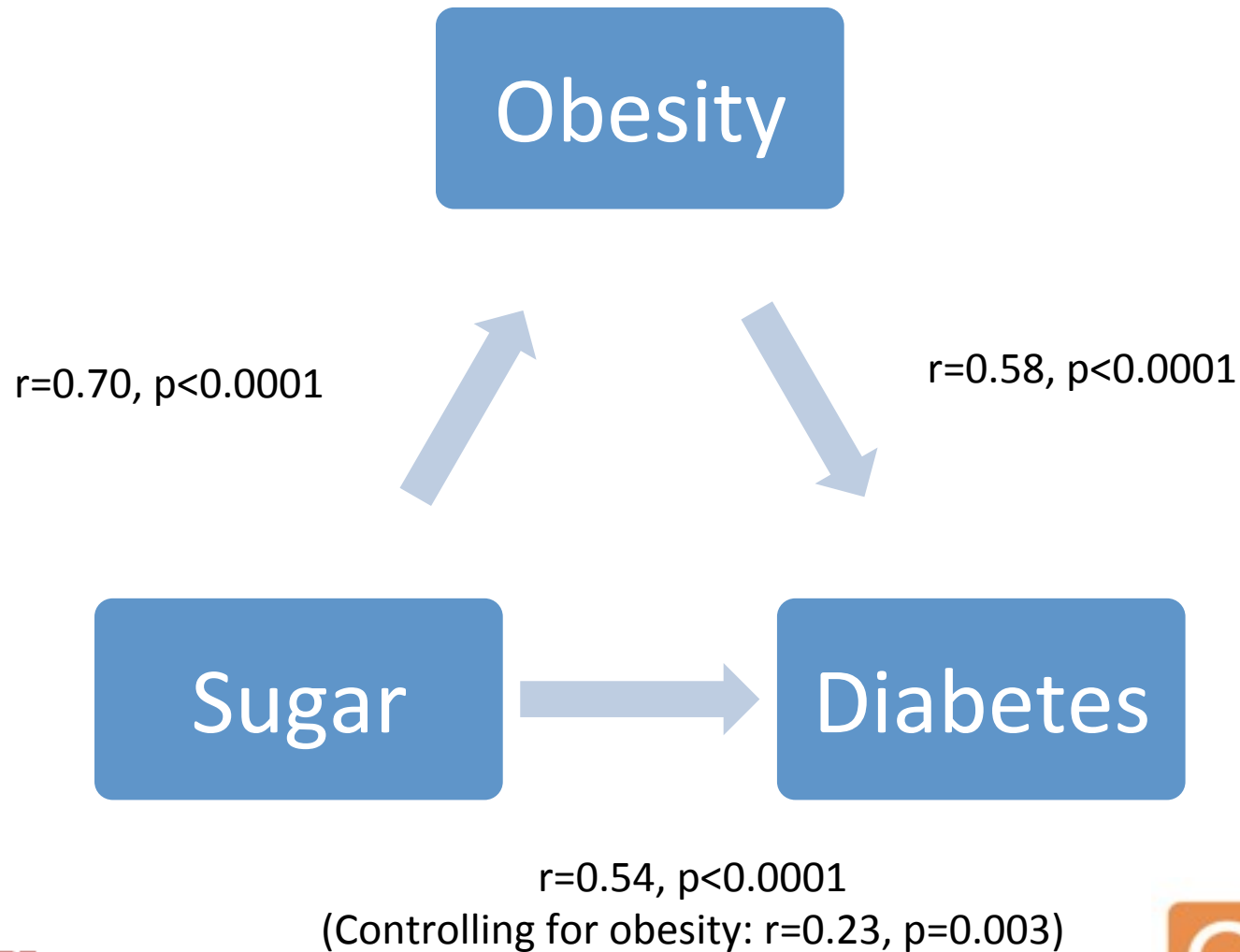
# Global Implications: Data from 170 Countries

	Mean $\pm$ SD	Range
Diabetes Prevalence (%)	6.8 $\pm$ 3.0	1.6 - 18.7
BMI (kg / m <sup>2</sup> )	24.9 $\pm$ 2.3	20.1 - 31.1
Total Intake (kcal / day per capita)	2711 $\pm$ 510	1559 - 3781
Total Sugar (kg / day per capita)	29.8 $\pm$ 16.0	2.2 - 68.6

# Global Influence of Sugar on Diabetes

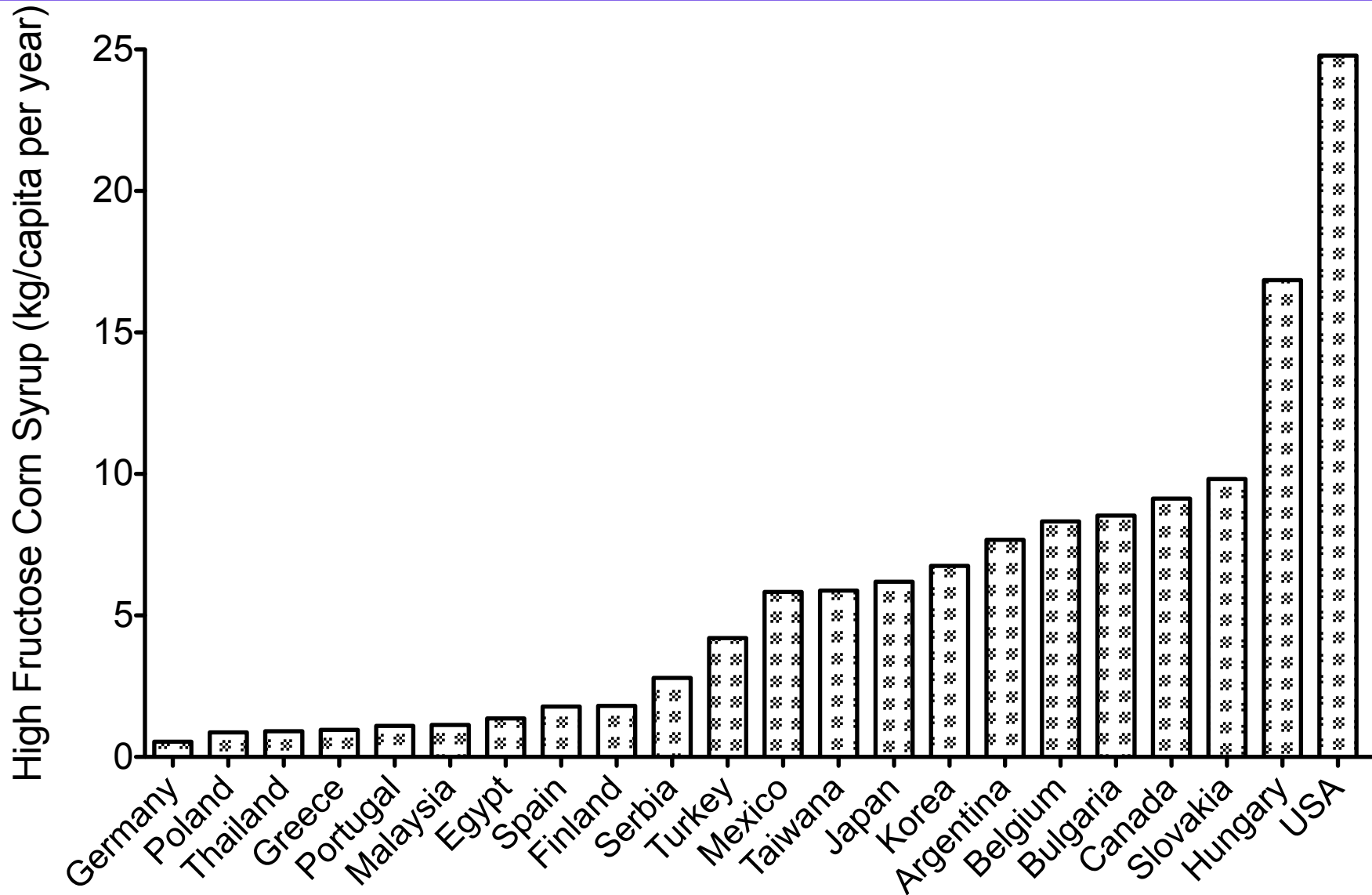


# Dietary Sugar is Associated with Obesity and Diabetes



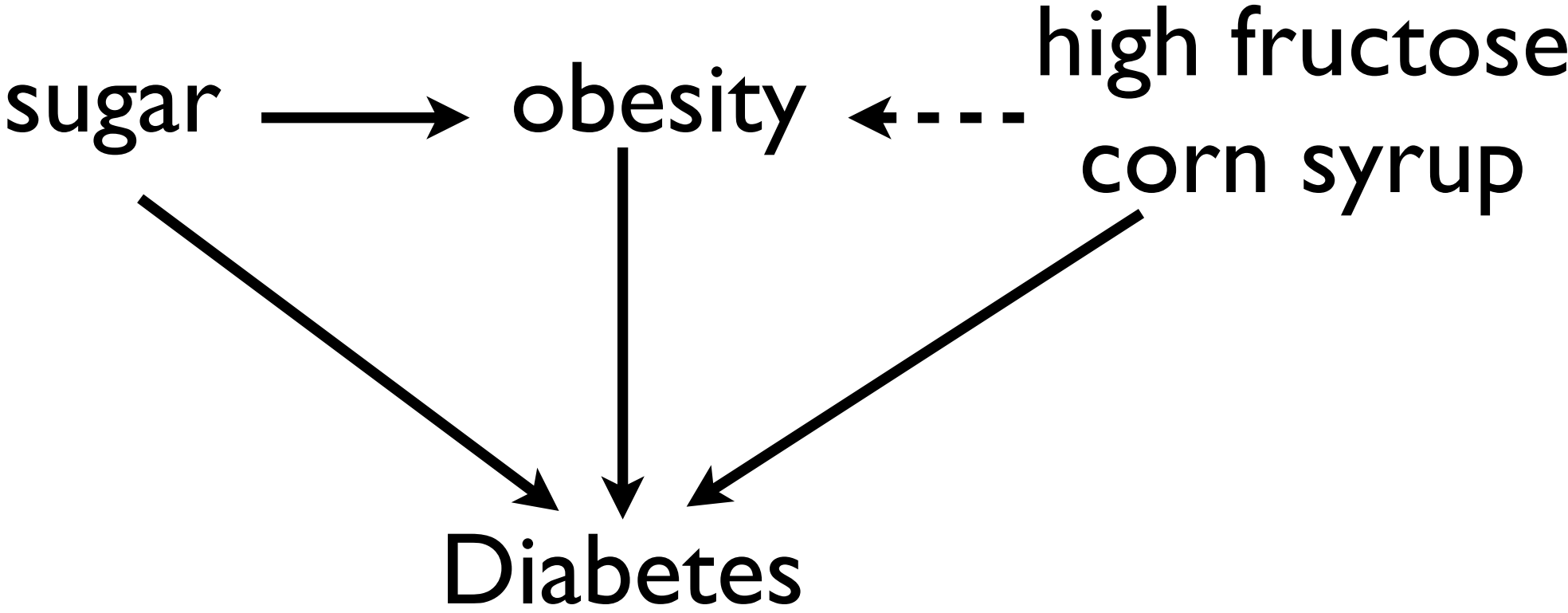


# Global Pattern in HFCS Use

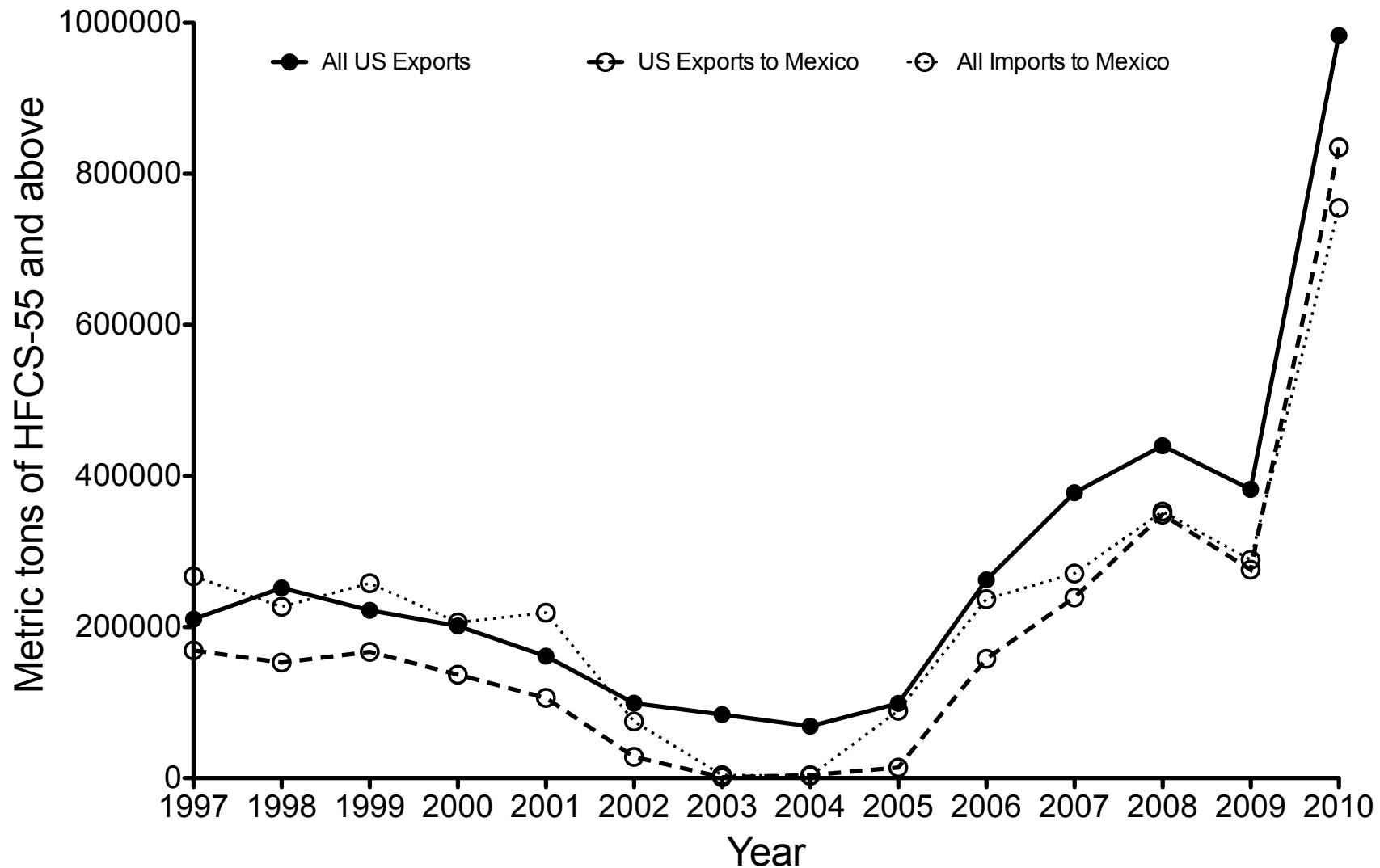


Zero or < 0.5kg per capita/year: Australia, China, Cyprus, Czech Republic, Denmark, Estonia, France, India, Indonesia, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Romania, Slovenia, Sweden, United Kingdom, Uruguay

	Countries not Using HFCS (n=22)	Countries Using HFCS (n=21)
BMI (kg / m <sup>2</sup> )	25.5 ± 1.6	25.9 ± 1.4
Total Intake (kcal / day per capita)	3230 + 377	3221 + 365
Total Sugar (kg / day per capita)	38.2 + 12.8	39.9 + 11.3
HFCS (kg / day per capita)	0.1 + 0.2	5.8 + 6.1
<b>Diabetes Prevalence (%)</b>	<b>6.7 + 1.3</b>	<b>7.9 + 1.8</b>
<b>Fasting Glucose (mmol/L)</b>	<b>5.23 + 0.17</b>	<b>5.33 + 0.17</b>



# HFCs Exports from the US to Mexico



## **Policy Implications:**

EU policy on HFCS quotas and their trading between countries may be a factor influencing that countries public health

Trade policy between countries in sugar and HFCS may be a factor driving public health

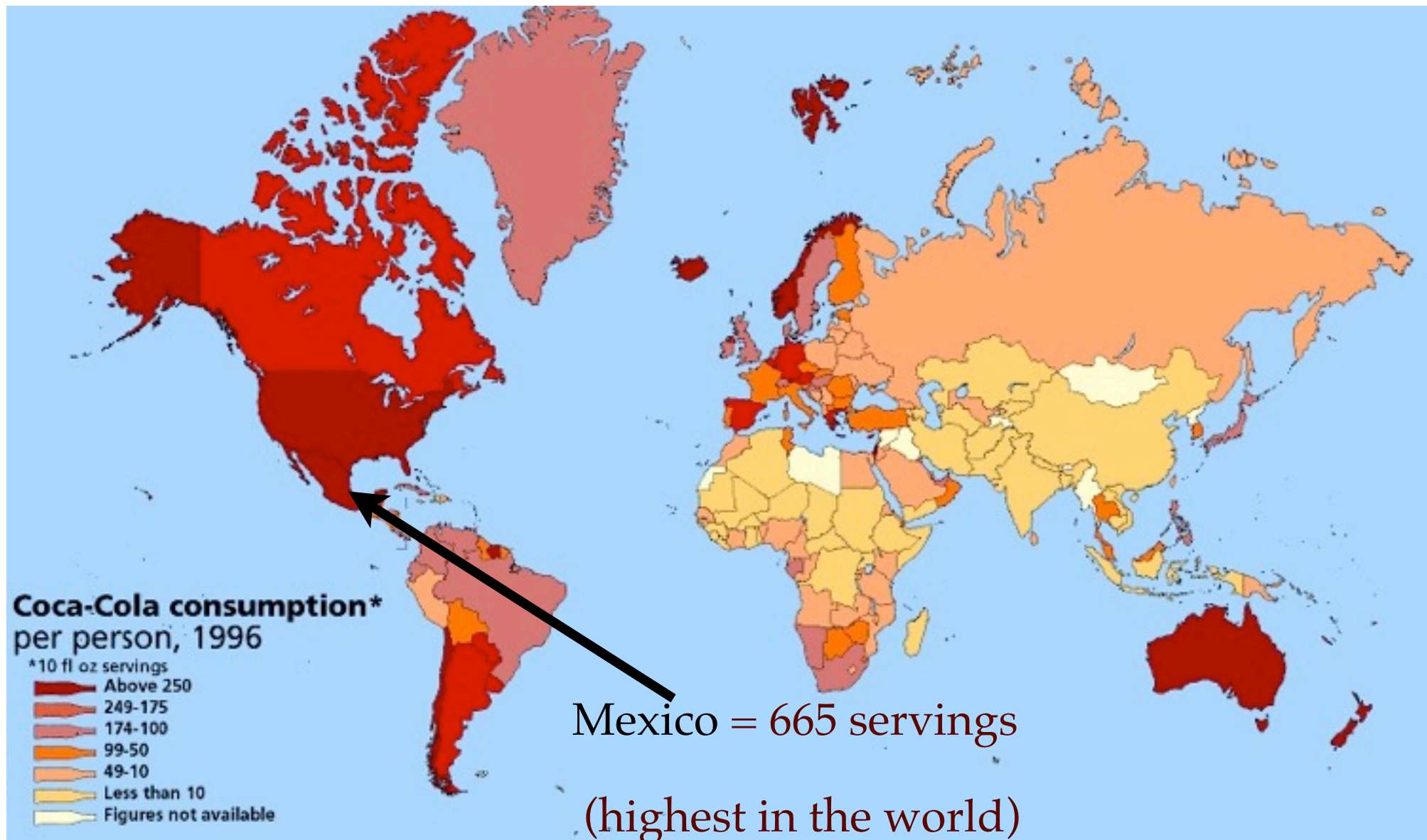
# Africa: Coke's Last Frontier

Cover story in Bloomberg Businessweek, Nov 1, 2010



- Per Capita consumption of coke in Kenya = 39 servings
- Mexico = 665 servings (highest in the world)
- Coke sales stagnant in developed countries (in the US: \$2.6b in 1989 vs \$2.9b in 1999)
- Coke plans to invest \$12b in Africa in next 10 years.

# Global Consumption of Coke

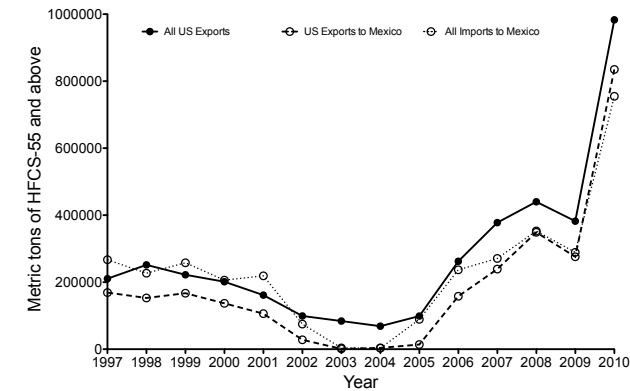
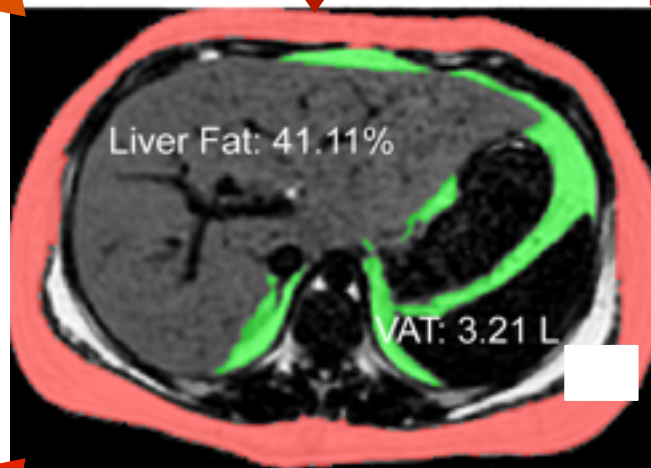


# Hispanics: A "perfect storm" for Fatty Liver

high prevalence of  
GG Genotype  
in PNPLA3

obesity

high sugar  
consumption:  
Mexico has highest  
consumption of coca-  
cola in the world



PNPLA3\* sugar  
interaction

liver disease  
liver cancer

insulin resistance  
type 2 diabetes

exponential  
increase in  
HFCS export to  
Mexico



# Simple Tips

- Avoid products with high fructose corn syrup
- Replace sugary drinks with water or dilute juice with water (50:50)
- Avoid foods with >10g sugar per serving
- Avoid flavored milk
- Watch for “hidden” sugar which can be high in surprising products (eg yogurts, breads)

# Summary

- Sugar is a contributing factor to obesity and related outcomes
- Double-edged sword: effects of sugar on obesity and separate effects on metabolic outcomes like diabetes
- Not all sugars are equal in their health effects - fructose is more damaging because of the way it is metabolized
- Dietary fructose is increasing because of HFCS - fructose content of foods made with HFCS is higher than we think
- The more we tip the balance towards increasing fructose, the greater the metabolic problems (diabetes, gout, hypertension)

# Acknowledgments



## Funding:

NICHD (ROI 33064)

NIDDK (ROI 59211)

NCI (U54 116848)

NCMHD (P60 002564)

ADA

Thrasher Foundation

Atkins Foundation

[www.GoranLab.com](http://www.GoranLab.com)