

# GI/GL/GR: definitions, methodology and issues.

Thomas MS Wolever, BA, MA, MSc, PhD, DM (Oxon)



Department of Nutritional Sciences,  
University of Toronto, Toronto, ON, Canada.

**St. Michael's**  
Inspired Care. Inspiring Science.

Keenan Research Centre of  
Li Ka Shing Knowledge Institute,  
St. Michael's Hospital, Toronto, ON, Canada.

 **Glycemic Index**  
Laboratories

Glycemic Index Laboratories, Inc.  
20 Victoria St., Suite 300, Toronto, ON, Canada.  
[www.gilabs.com](http://www.gilabs.com)

# Meal Planning for Diabetes

## Meal Plan

<b>TIME</b>	Breakfast	Lunch	Dinner	Snack			
<b>CARBOHYDRATES</b> <i>(grams / choices)</i>	3	3	4	3			
<b>GRAINS &amp; STARCHES</b>	1½	2	2	2			
<b>FRUITS</b>	1	1	½				
<b>MILK &amp; ALTERNATIVES</b>	½		½				
<b>OTHER CHOICES</b>			1				
<b>VEGETABLES</b>							
<b>MEAT &amp; ALTERNATIVES</b>							
<b>FATS</b>							

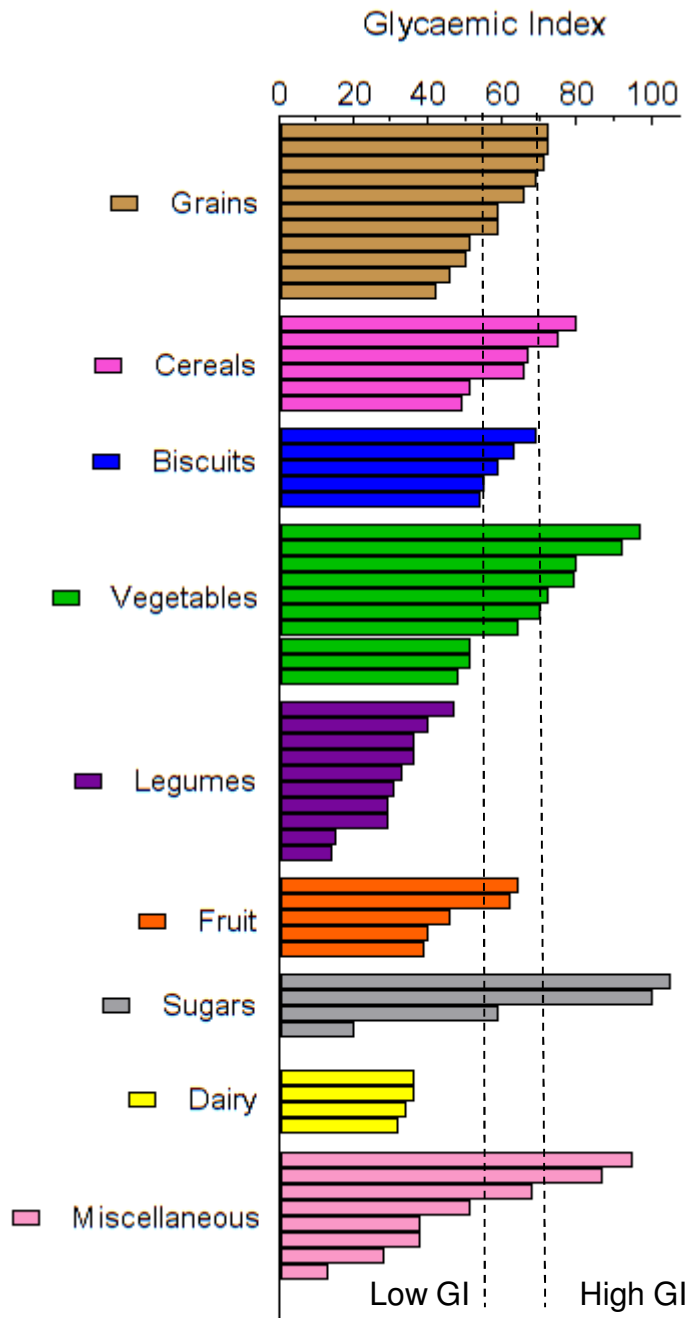
<http://www.diabetes.ca/files/Meal%20plan%20web.pdf>

Accessed 15 May, 2013

# Carbohydrate Counting

**Starches contain 15 grams of carbohydrate and 80 calories per serving. One serving equals:**

SERVING	FOOD
1 slice	Bread (white, pumpernickel, whole wheat, rye)
1/4 (1 oz)	Bagel (varies)
1/2	English muffin
1/2	Hamburger bun
3/4 C	Cold cereal
1/3 C	Rice, brown or white, cooked
1/3 C	Barley or couscous, cooked
1/3 C	Legumes (dried beans, peas or lentils), cooked
1/2 C	Pasta, cooked
1/2 C	Bulgar, cooked
1/2 C	Corn, sweet potato, or green peas
3 oz	Baked sweet or white potato
3 C	Popcorn, hot air popped or microwave (80% light)



Jenkins et al. Am J Clin Nutr 1981;34:362

# Definition: Glycemic Index

The incremental area under the blood glucose response curve elicited by a 50g available carbohydrate portion of a test food expressed as a percentage of the response after 50g glucose in the same subject.

$$GI = 100 \times F/G$$

$$GI = \frac{\sum_{x=1}^n 100 \times F_x / \bar{G}_x}{n}$$

# Glycemic Index: Current Issues / Criticisms

- GI does not predict glycemic impact.
- GI method is inaccurate and imprecise.
- Measured GI of mixed meal  $\neq$  calculated GI.
- Many food factors influence the results.

# GI Does not Predict Glycemic Impact

- GI is not a glycemic response.

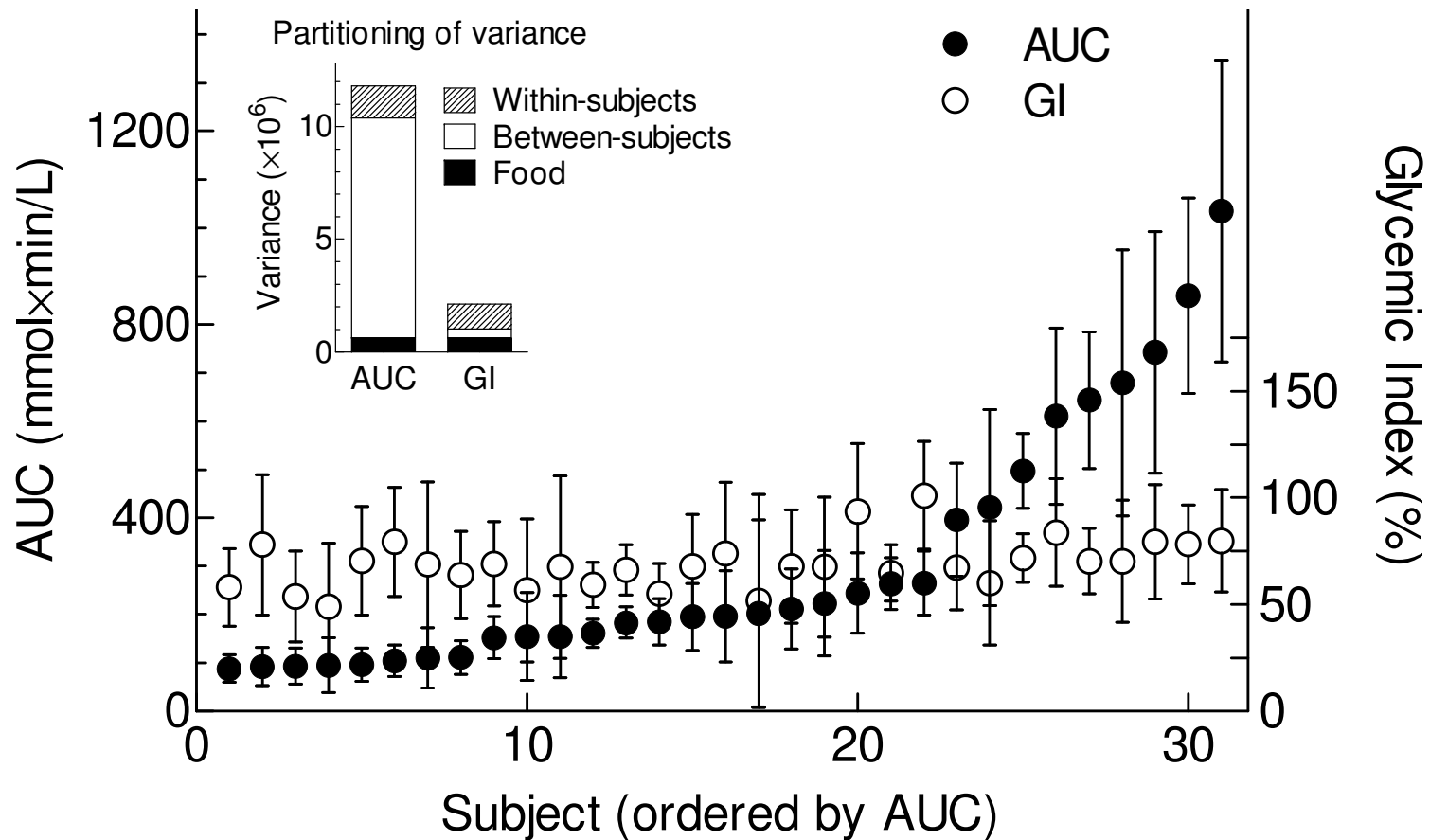
# Glycemic Response

- AACCI Definition
  - The change in blood glucose concentration induced by ingested food.



# GI vs Glycemic Response

## GI is a Property of Foods

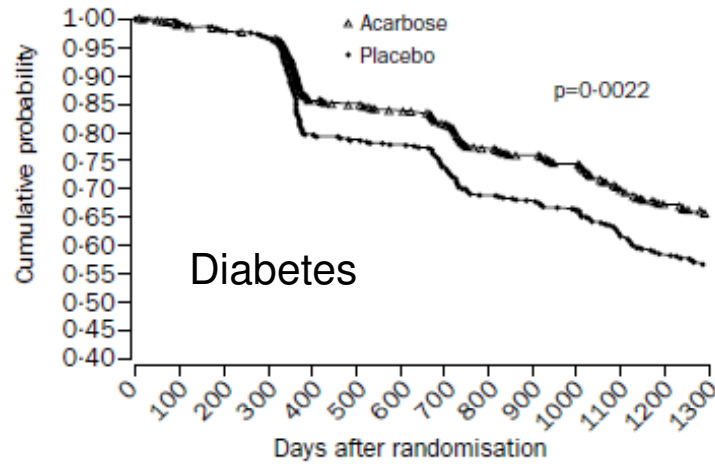


# GI Does not Predict Glycemic Impact

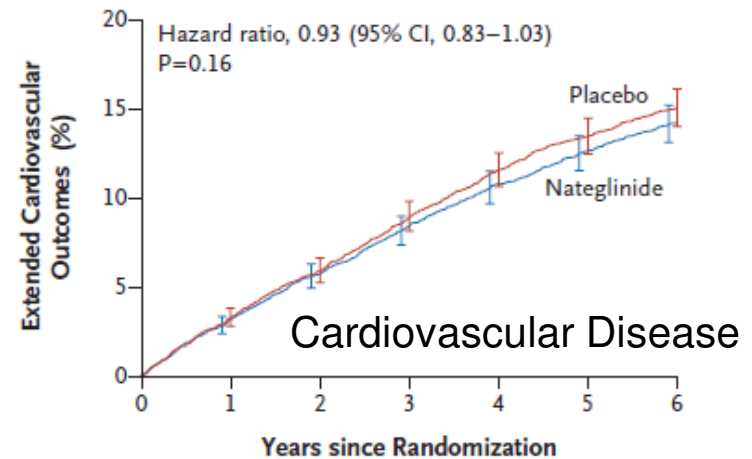
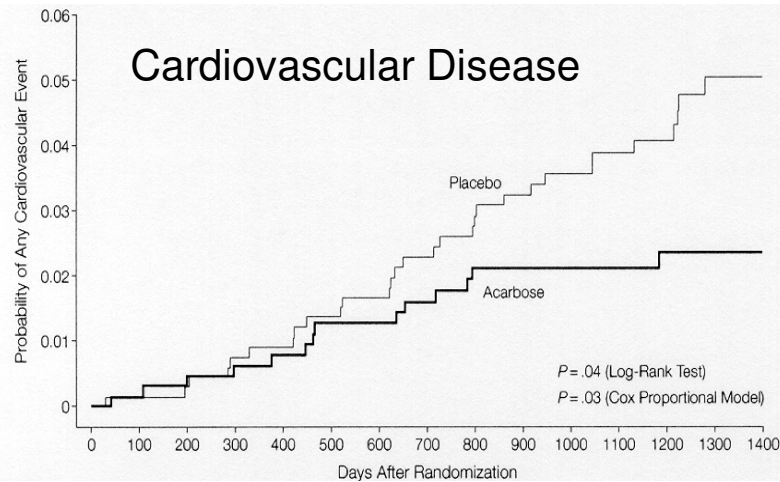
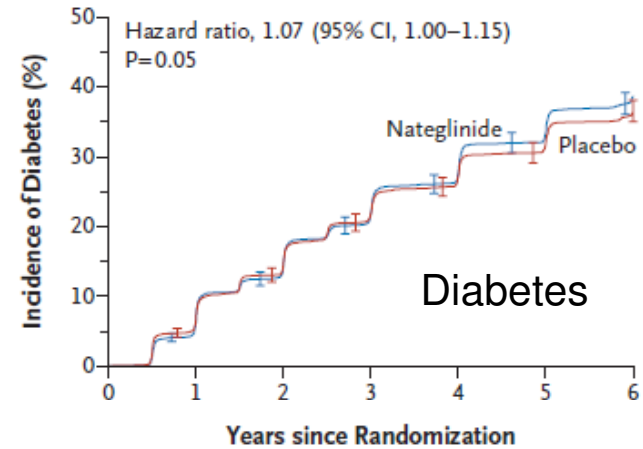
- GI is not a glycemic response.
- Is it beneficial to reduce “glycemic impact”?

# Treatment of IGT with:

## Acarbose



## Nateglinide



Lancet 2002;359:2072. & JAMA 2003;290:486.

New Eng J Med 2010;362:1463.

# GI Does not Predict Glycemic Impact

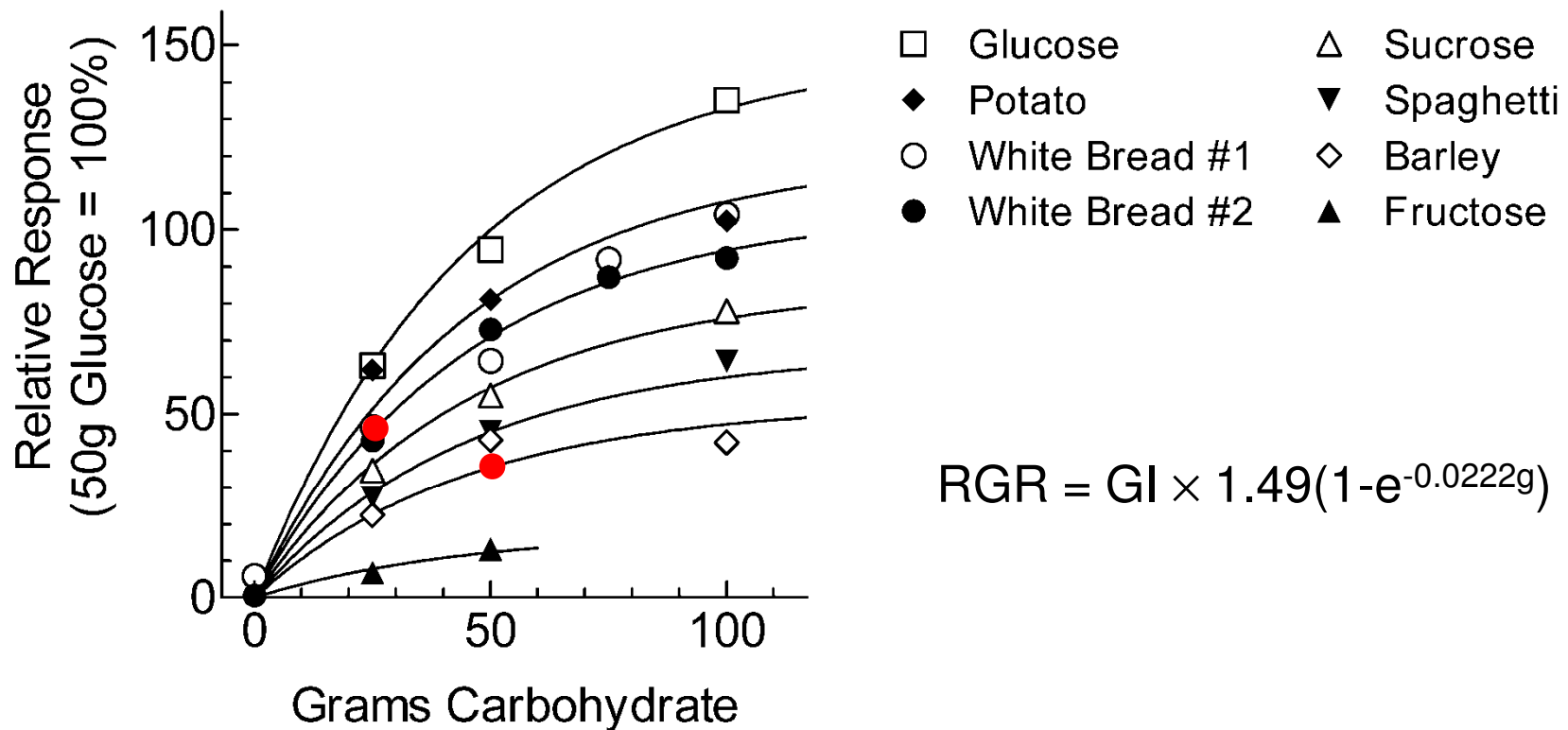
- GI is not a glycemic response.
- Is it beneficial to reduce “glycemic impact”?
  - Not necessarily.
- GI independent of amount of CHO
  - Not all meals contain 50g available CHO

# Glycemic Load

- Glycemic Load:  $GL = g \times GI / 100$ 
  - Reflects CHO quality and quantity
  - **Quantitative**: 1 unit = glycemic impact of 1g glucose

# Problems with Glycemic Load

- Dose-response curve is not linear.



# Problems with Glycemic Load

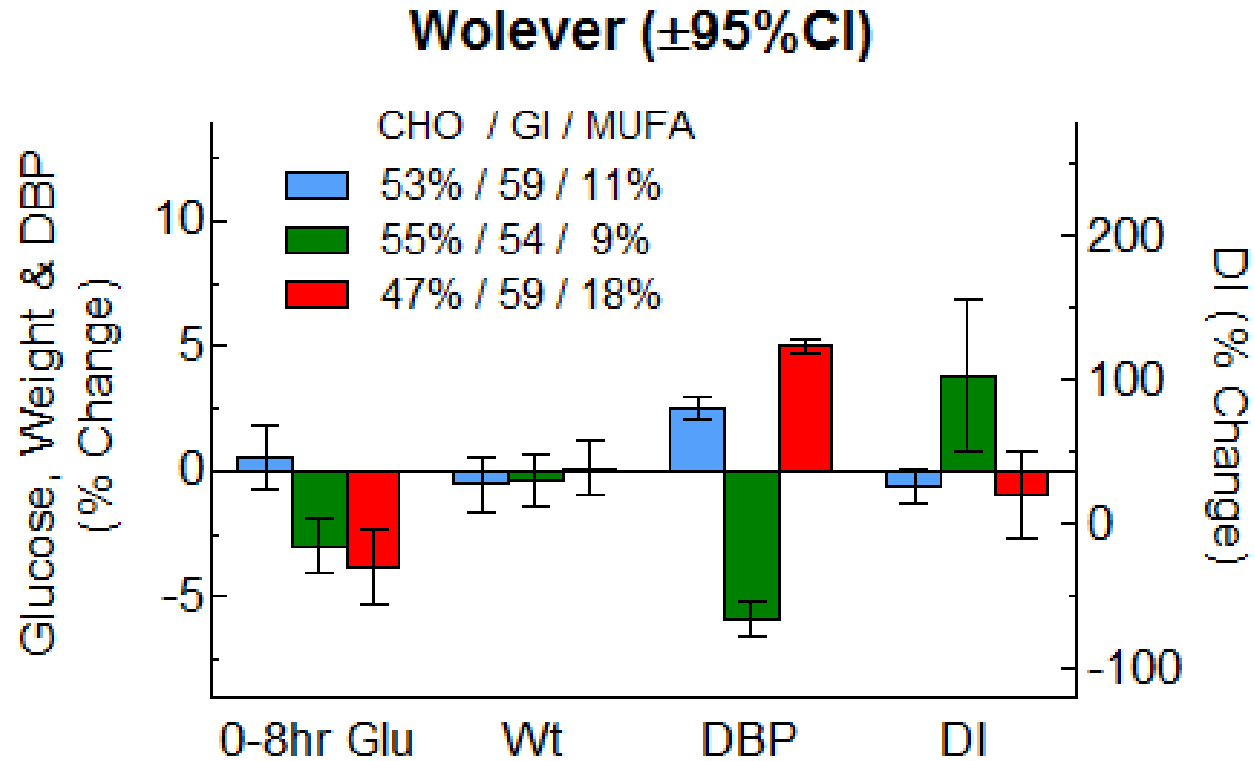
- What is the definition?
  - **Perceived** definition:  $GL = g \times GI / 100$ 
    - GL of 2 apples =  $2 \times$  GL of 1 apple
  - **Actual** definition: GL adjusted for energy
    - Salmeron et al. JAMA 1997;277:472
    - GL of 2 apples = GL of 1 apple
  - GL is confounded by energy
  - GI is not confounded by energy

# Problems with Glycemic Load

- Different ways to reduce GL
  - Reduce amount of CHO or reduce GI or both
  - These maneuvers have different long-term effects

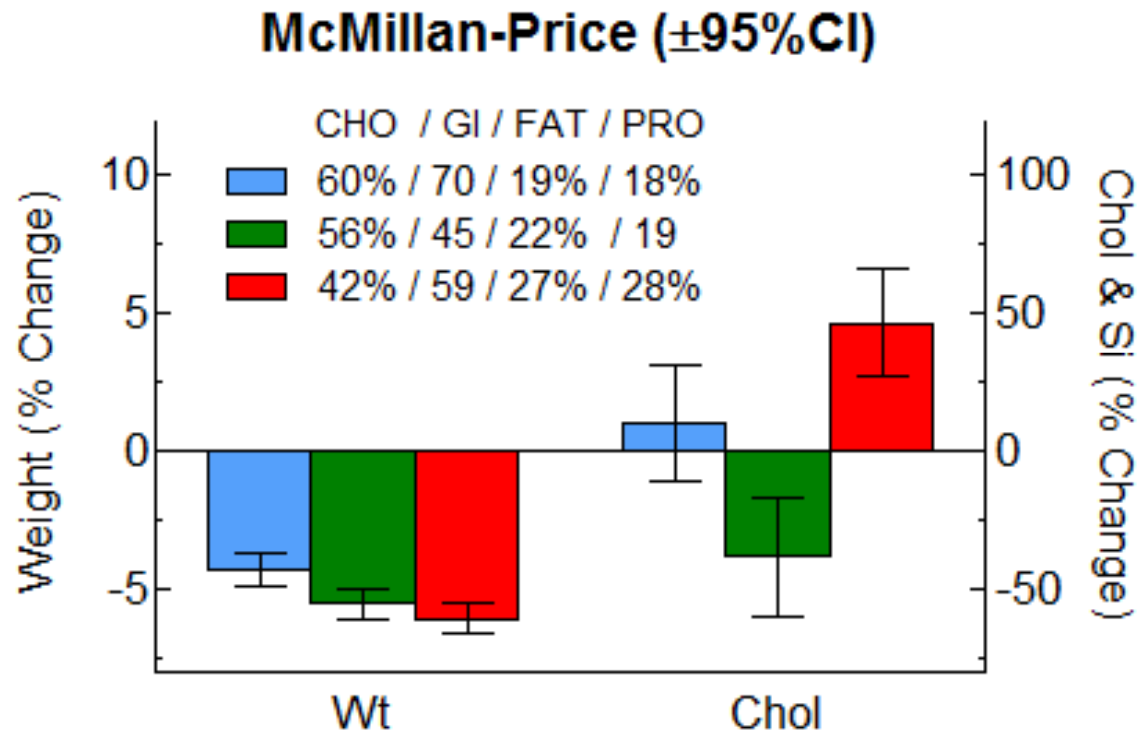


# Low CHO vs Low GI



Wolever & Mehling *Brit J Nutr* 2002;87:477 & *Am J Clin Nutr* 2003;77:612.

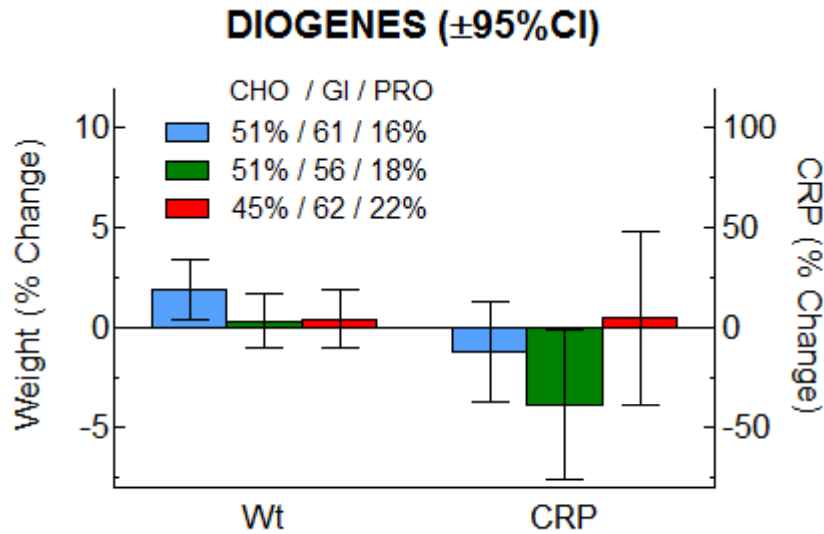
# Low CHO vs Low GI



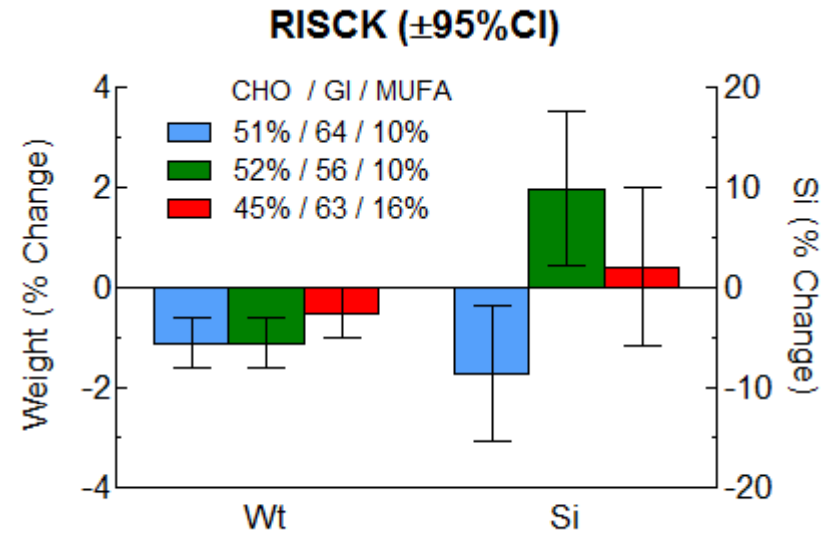
McMillan-Price J et al. Arch Int Med 2006;166:1466.

n=32-33 per group

# Low CHO vs Low GI



Gögebakan Ö et al. Circulation 2011;124:2829.

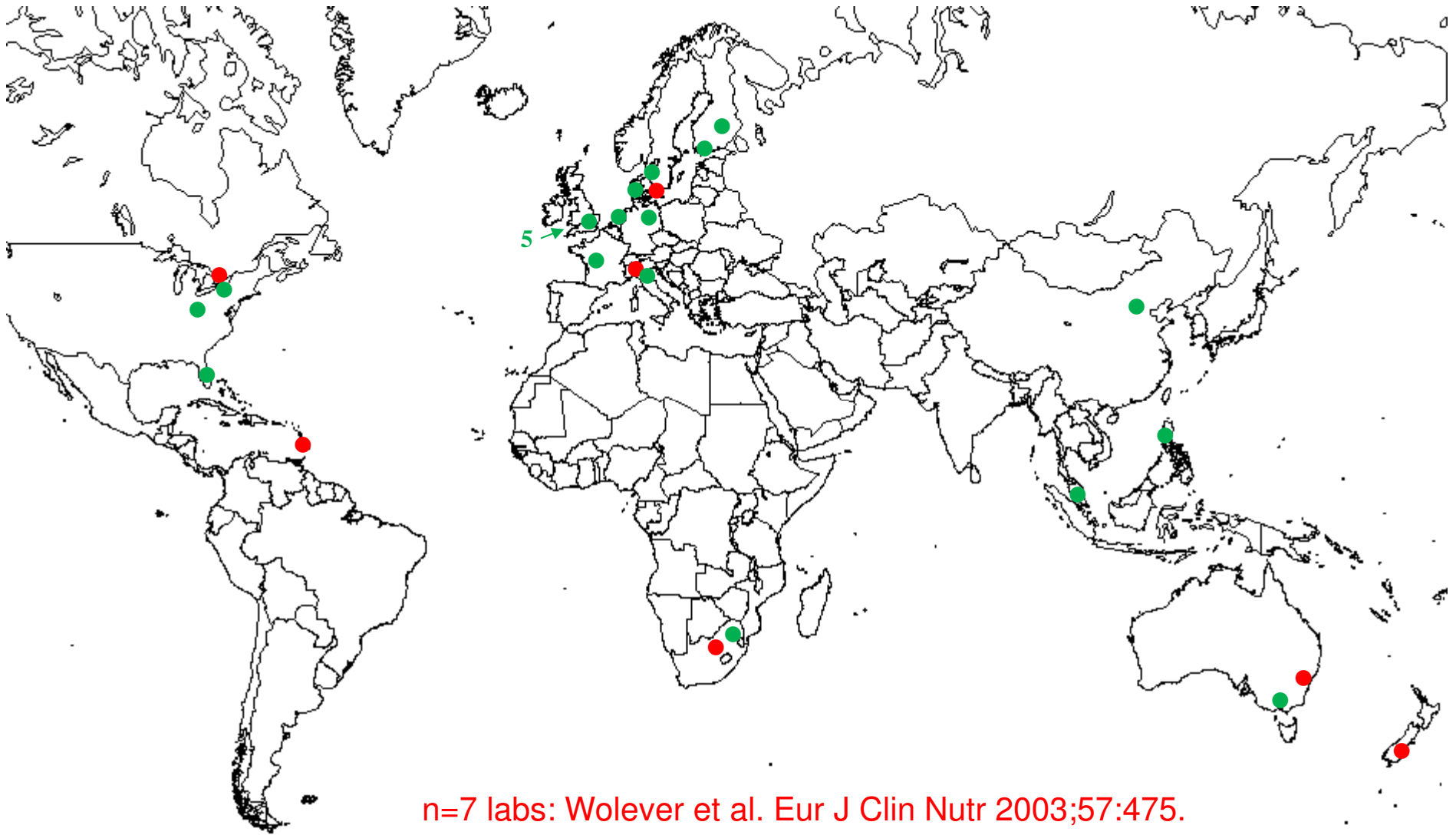


Jebb SA et al. AJCN 2010;92:748.

# Glycemic Index: Current Issues / Criticisms

- ~~GI does not predict glycemic impact.~~
  - Quality is more important than quantity.
- GI method is inaccurate and imprecise

# GI Inter-laboratory Studies



n=7 labs: Wolever et al. Eur J Clin Nutr 2003;57:475.

n=28 labs: Wolever et al. Am J Clin Nutr 2008;87(suppl):S247.

# Factors Affecting Accuracy and Precision of GI

- Accuracy (mean value)
  - Definition of available carbohydrate
  - Blood sampling schedule
  - Method of AUC calculation
  - Within-subject variation
  - Handling of outliers
- Precision (confidence interval)
  - Subject preparation
  - Drink with test meal
  - Precision of glucose analysis
  - Number of subjects

# Evolution of GI Methodology

Methodological Procedure	Original 1981	FAO 1998	Interlab 2003	Brouns 2005	Interlab 2008	ISO 2010
Time of day / subj. prep: Morning after overnight fast	✓	✓	✓	✓	✓	✓
Test meal portion size: 50g available CHO	✓	✓	✓	✓	✓	✓
Blood sample schedule: 0, 15, 30, 45, 60, 90 & 120min	✓	✓	✓	✓	✓	✓
AUC calculation: Inc. ignoring area below fasting	✓	✓	✓	✓	✓	✓
Reference (Glucose=100)	✓		✓		✓	✓
Test repeated in each subject	✓	✓	✓	✓	✓	✓
Calculation of GI: Mean of $100 \times F/\bar{G}$ for each subject	✓	✓	✓	✓	✓	✓
n ≥10 subjects				✓	✓	✓
Reference CV <30%				✓	✓	✓
Exclusion of outliers					✓	✓
2 fasting blood samples					✓	✓
Analytical CV <3.6%					✓	✓

# GI Method is Imprecise

- Julie Jones
- Jon DeVries
- Alfred Aziz (Health Canada)
- Harvey Anderson

Centre	Potato	Bread	Rice	Spaghetti	Barley
A	86.1 ± 29.7	78.7 ± 28.4	54.8 ± 24.1 <sup>X</sup>	38.7 ± 13.2 <sup>X</sup>	36.0 ± 15.4
B	93.3 ± 32.5	64.2 ± 15.4	62.6 ± 25.0 <sup>XY</sup>	44.1 ± 19.8 <sup>XY</sup>	31.4 ± 18.7
C	89.9 ± 23.9	64.6 ± 21.6	85.0 ± 28.6 <sup>Y</sup>	69.9 ± 18.8 <sup>Y</sup>	46.2 ± 15.4
D	98.5 ± 20.6	69.4 ± 3.6	63.3 ± 8.1 <sup>XY</sup>	43.8 ± 9.2 <sup>XY</sup>	24.5 ± 7.3
E	88.3 ± 21.3	78.9 ± 26.1	76.9 ± 12.9 <sup>XY</sup>	42.1 ± 10.8 <sup>XY</sup>	39.3 ± 13.1
F	65.2 ± 44.6	75.8 ± 64.3	68.4 ± 48.0	36.4 ± 35.8	23.2 ± 24.6
G	74.2 ± 40.3	75.9 ± 50.7	87.0 ± 75.9	57.0 ± 45.3	47.1 ± 49.7
All <sup>a</sup>	84.5 ± 32.7 <sup>A</sup>	72.5 ± 35.8 <sup>A</sup>	71.1 ± 38.2 <sup>A</sup>	46.9 ± 26.7 <sup>B</sup>	34.7 ± 24.7 <sup>B</sup>
Venous <sup>b</sup>	69.0 ± 42.0 <sup>AB</sup>	75.8 ± 57.5 <sup>A</sup>	76.4 ± 60.5 <sup>A</sup>	45.2 ± 40.4 <sup>BC</sup>	33.4 ± 38.4 <sup>BC</sup>
Capillary <sup>c</sup>	91.5 ± 25.1 <sup>A</sup>	71.0 ± 20.7 <sup>B</sup>	68.7 ± 22.6 <sup>B</sup>	47.6 ± 18.1 <sup>C</sup>	35.2 ± 15.6 <sup>C</sup>

Rice: mean=71, SD=38, therefore 95% CI = -5 to 147

Disappointing error:

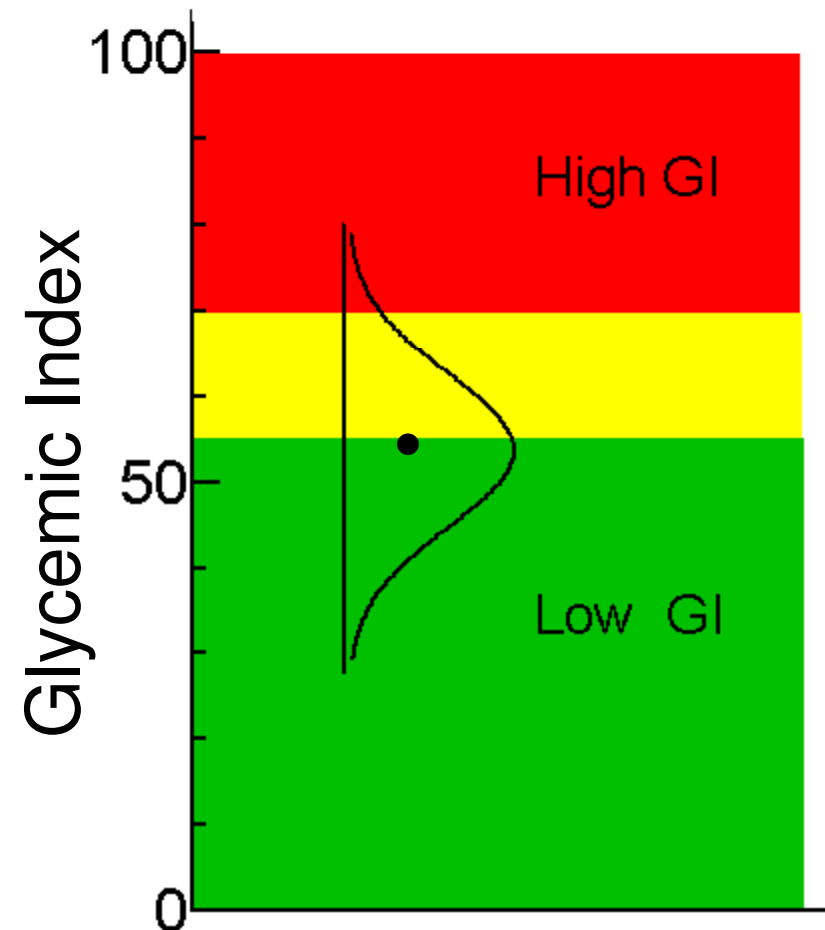
- 95%CI -5 to 147 is for estimates in individual subjects



# Is GI Precise Enough for Clinical Use?

Can the method distinguish between High- and Low-GI?

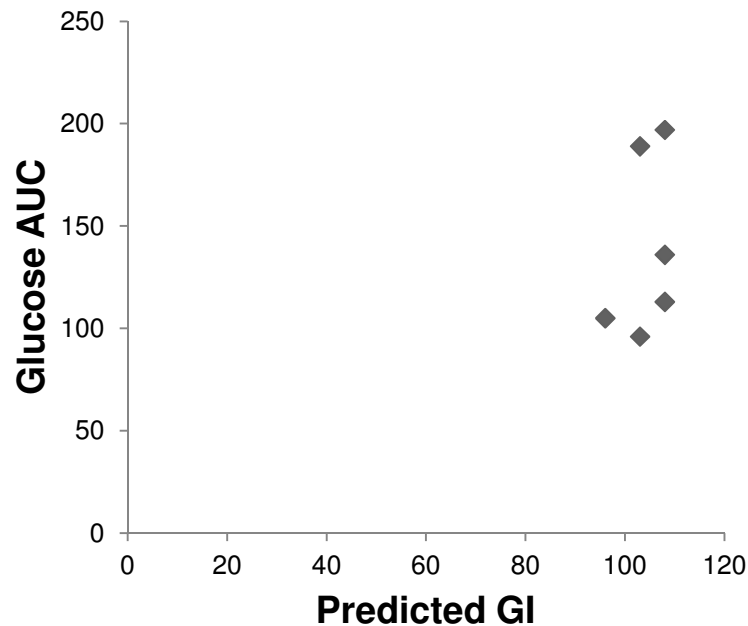
- Distinguishes High vs Low GI with 95% certainty



# Glycemic Index: Current Issues / Criticisms

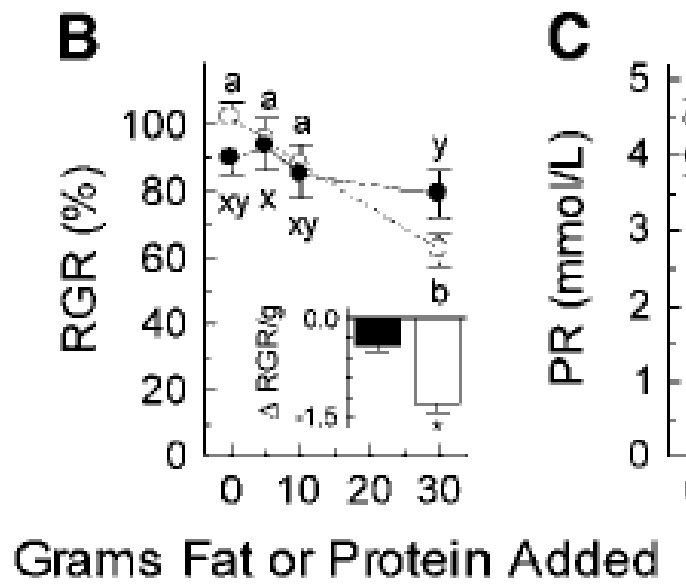
- ~~GI does not predict glycemic impact.~~
  - Quality is more important than quantity.
- ~~GI method is inaccurate and imprecise~~
  - GI is precise enough for clinical use.
- Measured GI of mixed meal  $\neq$  calculated GI.

	avCHO (g)	Fat (g)	Protein (g)	Energy (mJ)
Potato	50	4	5	1.1
Potato & Oil	50	34	5	2.2
Potato & Chicken	50	10	35	1.8
Potato & Salad	54	4	6	1.2
Potato & oil & chicken & salad	54	41	36	3.0
Potato & oil & chicken & salad & rye bread	54	45	38	3.1

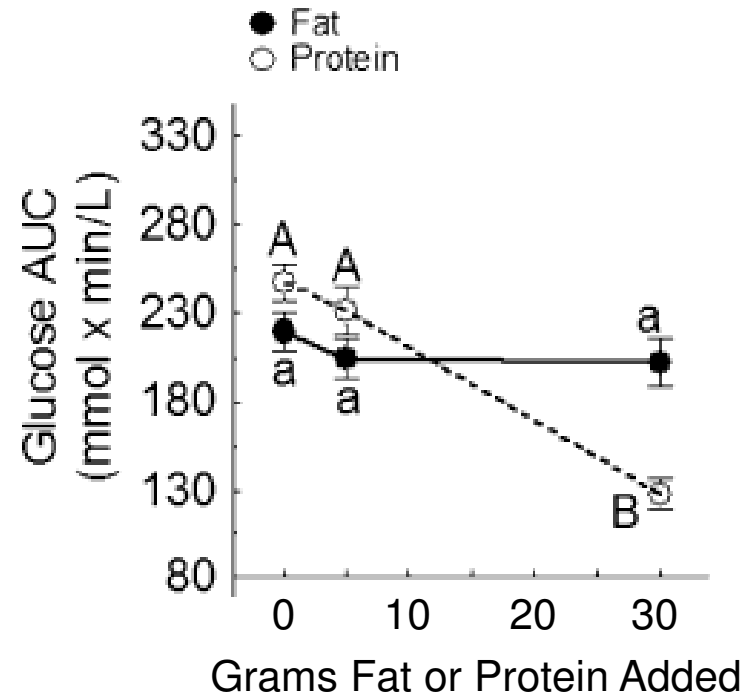


Hätönen et al. Brit J Nutr 2011;106:248

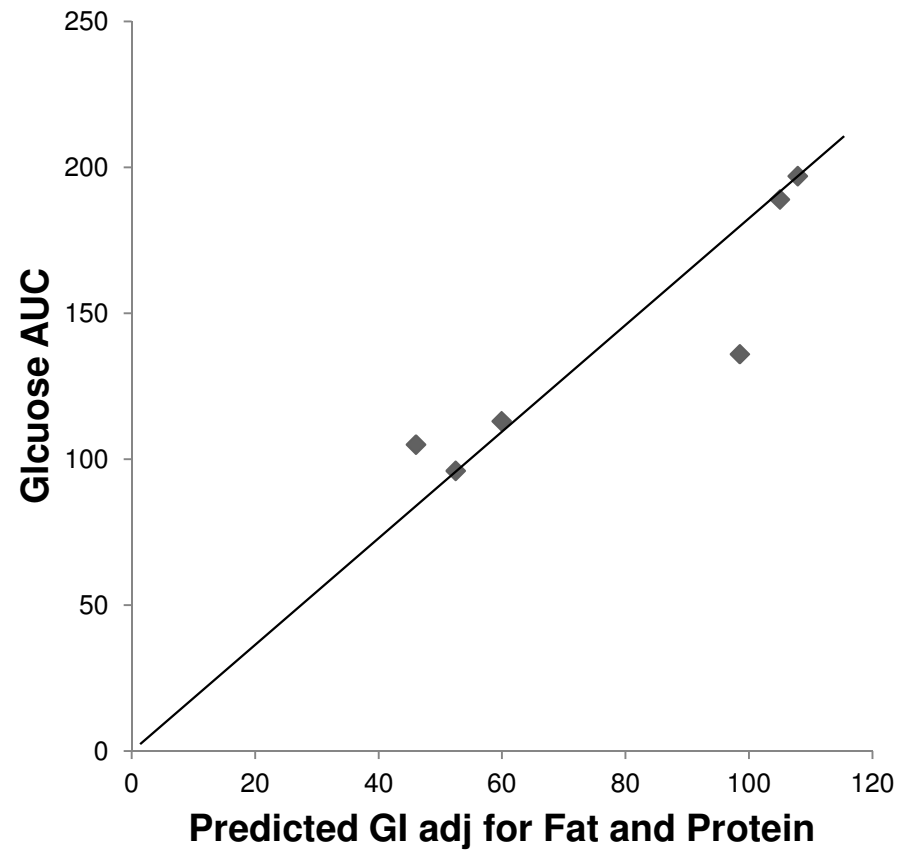
Conclusion:  
 "...the estimation of the GI of a mixed meal by calculation is imprecise."



Moghaddam et al. J Nutr 2006;136:2506.



Lan-Pidhainy & Wolever.  
Am J Clin Nutr 2010;91:98.

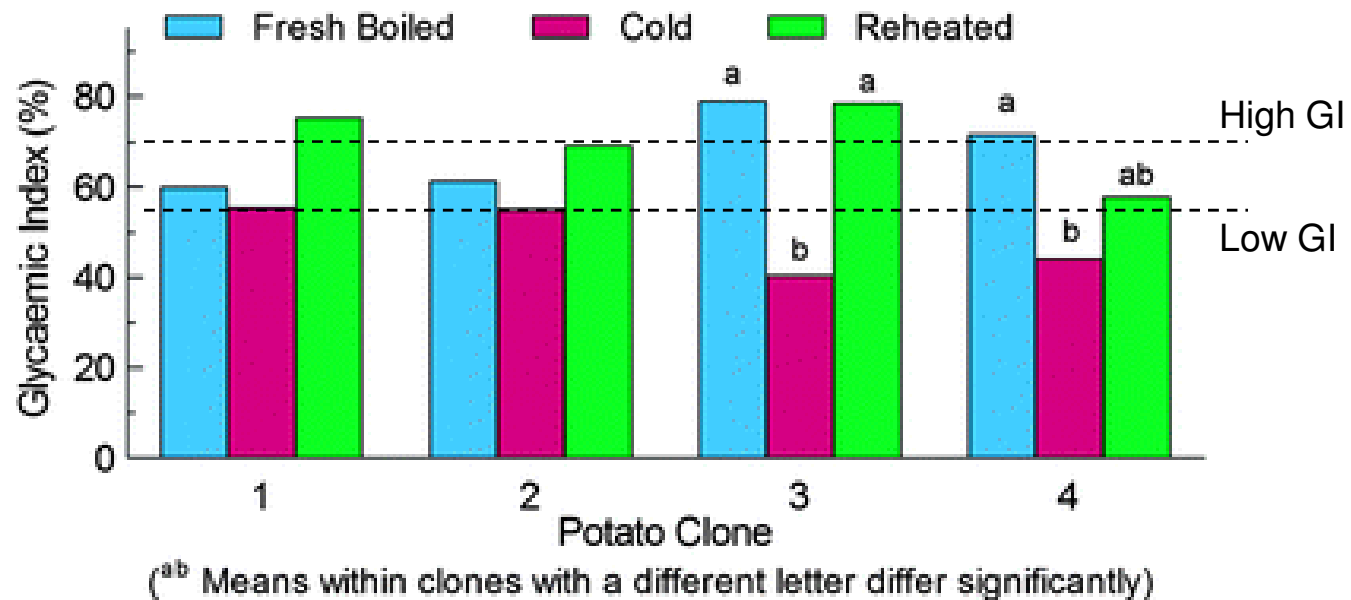


Wolever. Eur J Clin Nutr 2013;67:522.

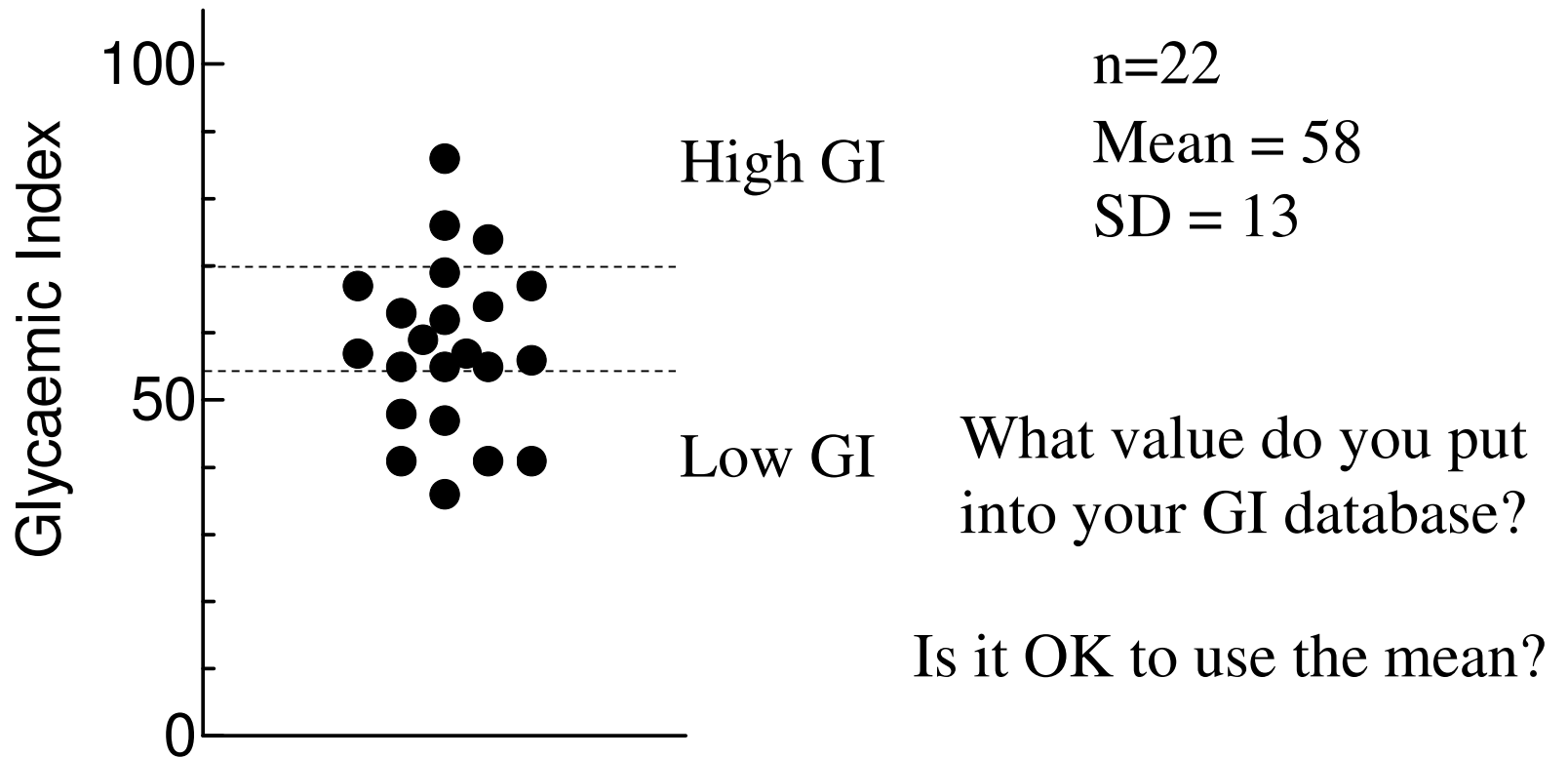
# Glycemic Index: Current Issues / Criticisms

- ~~GI does not predict glycemic impact.~~
  - Quality is more important than quantity.
- ~~GI method is inaccurate and imprecise~~
  - GI is precise enough for clinical use.
- Measured GI of mixed meal  $\neq$  calculated GI.
  - Of course not!
  - Meal glycemic response depends on:
    - Calculated GI of meal CHO
    - Amount of CHO
    - Amounts (and types) of fat and protein

# Many food factors influence GI



# Rye Bread



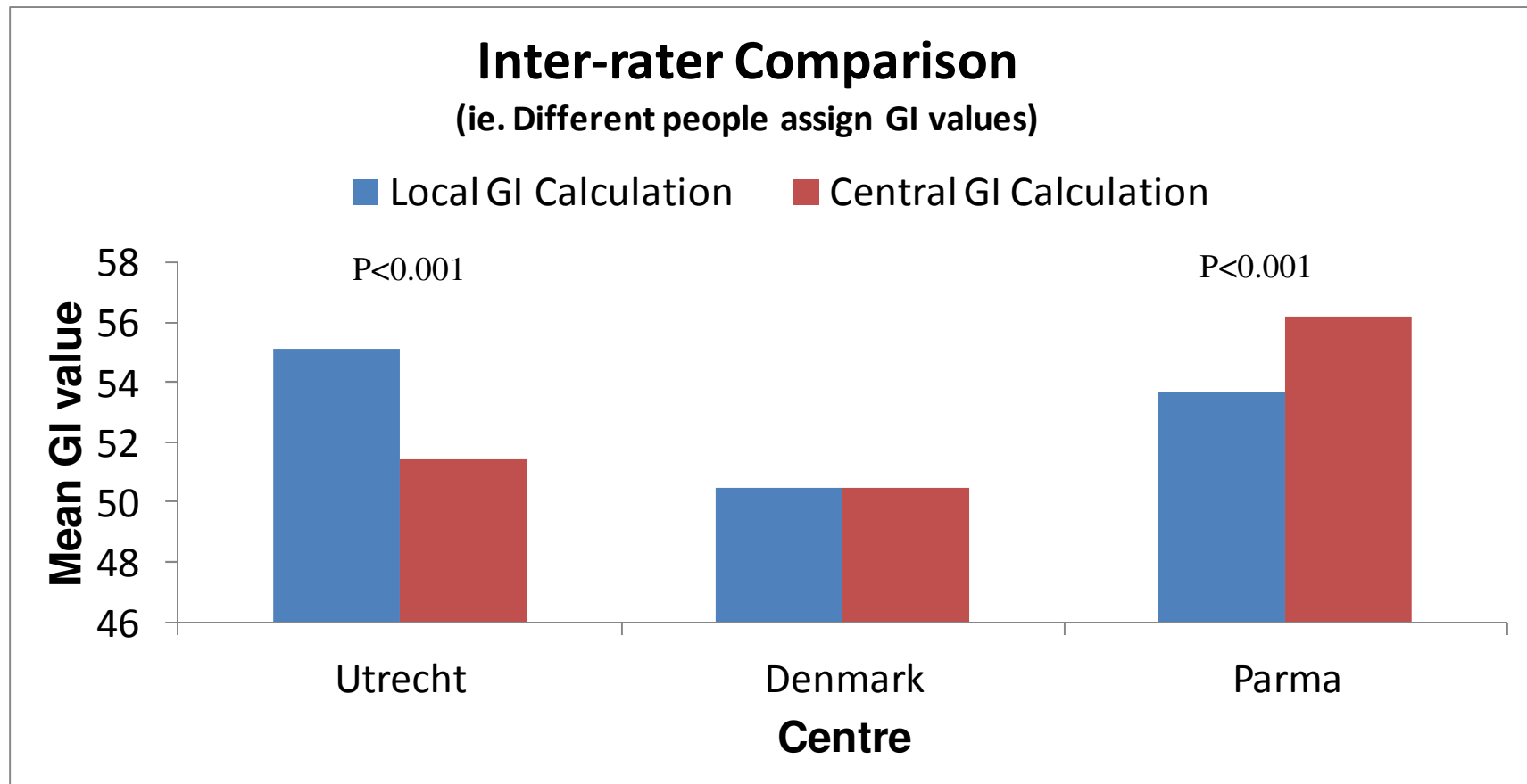
Yes - IF the variation is random.

But variation is NOT random; it is WRONG to use the mean.



# Methodological challenges to application of GI in epidemiological studies...

van Bakel et al. J Nutr 2009;139:568-75.



# Conclusions - 1

- Current criticisms of GI
  - Many concerns are not valid
  - Rather they reflect poor knowledge translation
- Problems:
  - Incorrect use of terminology
  - Inappropriate methods often used
  - The GI of specific foods not known.
    - Research results may be biased
    - Clinical use difficult

# Conclusions - 2

- Possible solutions
  - Education about meaning of GI
    - Use correct terminology
  - Laboratory standardization / accreditation
    - Use correct methodology
  - GI Labeling
    - Provide reliable information to consumers and health professionals
- How to get there
  - Academic / Government / Industry collaboration