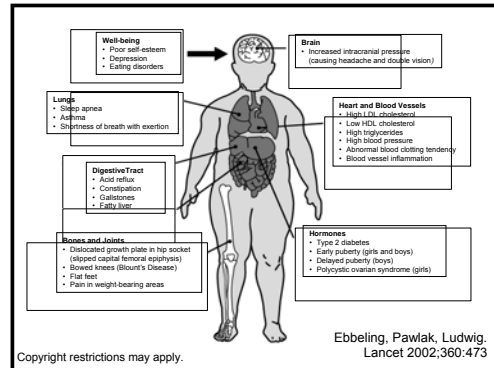


## Low Glycemic Load Diets for Treating Childhood Obesity

Cara B. Ebbeling, PhD  
 Research Co-Director, Optimal Weight for Life Program  
 Children's Hospital Boston  
 Assistant Professor of Pediatrics  
 Harvard Medical School

March 26, 2010

## Complications of Childhood Obesity



## Treatments for Childhood Obesity

### Systematic Review of Randomized Trials

Intervention	Eligible Trials 1967-2006 (n)
Pharmacological	17
Dietary	6
Physical activity	20
Combined lifestyle	30

"The long-term efficacy and safety of pediatric obesity treatments remain unclear."

McGovern et al.  
 J Clin Endocrinol Metab 2008; 93:4600

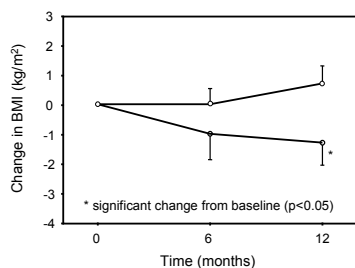
## Dietary Treatments for Childhood Obesity

### Systematic Review of Randomized Trials

- Hypocaloric diet
- Low-fat diet
- Low-carbohydrate diet
- Protein-sparing modified fast
- Low-glycemic load diet

McGovern et al.  
 J Clin Endocrinol Metab 2008; 93:4600

## Adolescent Pilot Study



○ Low-Glycemic Load Diet (n=7)  
 ○ Low-Fat Diet (n=7)

Ebbeling et al.  
 Arch Pediatr Adolesc Med 2003; 157:773

## Presentation Overview

### Question #1

- How are foods classified using the principles of glycemic index and glycemic load?

### Question #2

- What is the proposed physiological mechanism linking glycemic index and glycemic load with body weight?

### Question #3

- Why is there inconsistency among intervention studies designed to compare diets that differ in glycemic index and glycemic load?

### Question #4

- What are the practical considerations for prescribing a diet that is low in glycemic index and glycemic load?

### Classification of Carbohydrate Based on Chemical Structure

**Simple**

**Glucose**  
(monosaccharide)

**Sucrose**  
(disaccharide)

**Complex**

**Starch**  
(polysaccharide)

### Classification of Carbohydrate Based on Physiological Effects

#### Glycemic Index

- Classification system based on the rise in blood glucose over a 2-hour postprandial period following consumption of a food portion containing a standardized amount of carbohydrate.

AUC, 50 g carbohydrate, test food

---

AUC, 50 g carbohydrate, reference (glucose)

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

### Dietary Fiber and Glycemic Index

- Soluble Fiber
- Integrity of Insoluble Fiber  
Extent of Food Processing

### Soluble Fiber

Increased viscosity of partially digested food in small intestine

↓

Increased thickness of unstirred water layer (prevents rapid carbohydrate absorption)

Soluble fiber is beneficial whether consumed as a natural component of food or in extracted form (supplement, enriched product).

Jenkins & Jenkins,  
Proc Soc Exp Biol Med 1985; 180

Copyright restrictions may apply.

### Whole Kernel

**Proposed Mechanisms – Food Structure**

- Undisrupted fiber may decrease accessibility of starch to digestive enzymes.
- Foods with increased solidity require more chewing during ingestion, and solidity may decrease the rate of gastric emptying.

Purified insoluble fiber has minimal effect on glycemic index. The integrity of insoluble fiber is an important consideration.

Copyright restrictions may apply. [http://en.wikipedia.org/wiki/Whole\\_grain](http://en.wikipedia.org/wiki/Whole_grain)

### Integrity of Soluble Fiber

**Food Structure**

**Greater and less sustained glycemic response** →

Grains

Whole grains - Cracked grains - Course flour - Fine flour

Minimally Processed

## Practicality Debate

### Skepticism

- Glycemic index is a complex dietary concept and may be too complicated for the average consumer to understand.

#### Variables that influence glycemic index

- Cooking methods (potatoes) and cooking time (pasta)
- Ripeness (fruit)
- Regional agriculture (rice)
- Acidity (vinegar)

### Optimism

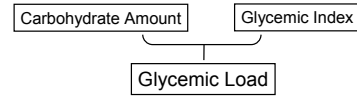
- The relevant concepts can be presented in a simple, understandable manner.

*More about presentation in a few minutes...*

## Considering Amount of Carbohydrate

### Glycemic Load

Arithmetic product of carbohydrate amount and glycemic index



$$\frac{\text{Carbohydrate (g)} \times \text{GI}}{100}$$

Salmeron et al. JAMA 1997;277:472  
Brand-Miller et al. J Nutr 2003;133:2728

## Comparisons

Example Foods and Portions	Carbohydrate (g)	Glycemic Index	Glycemic Load
Potato / 1 each, 170 g	43	85	37
Carrots / 0.5 c, 78 g	8	47	4
Apple / each, 154 g	22	38	8
Apple juice / 1 cup	29	40	12
Soft drink / 20 fl oz	68	63	43
Milk / 1 cup	12	27	3
Instant rice / 0.75 cup, 124 g	26	91	24
Spaghetti / 0.75 cup, 105 g	30	44	13
Lentils / 0.5 cup, 99 g	20	29	6
Broccoli, raw / 1 cup	5	--	--

Foster-Powell, Miller. Am J Clin Nutr 2002;76:5

## Presentation Overview

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- How are foods classified using the principles of glycemic index and glycemic load?

### Question #2

- What is the proposed physiological mechanism linking glycemic index and glycemic load with body weight?

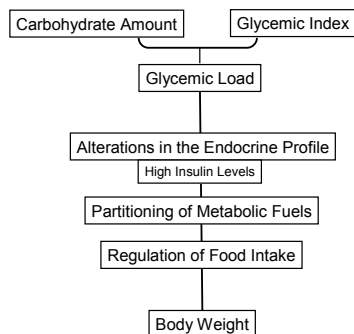
### Question #3

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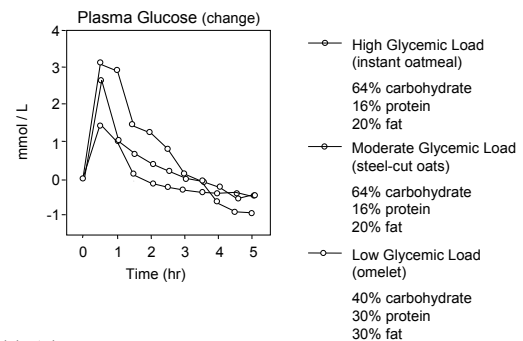
- What are the practical considerations for prescribing a diet that is low in glycemic index and glycemic load?

## Physiologic Mechanisms

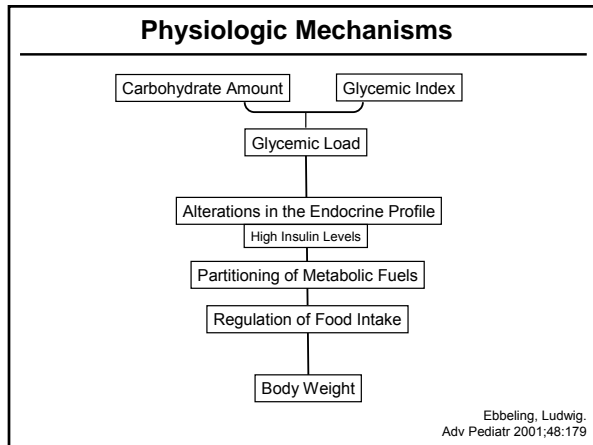
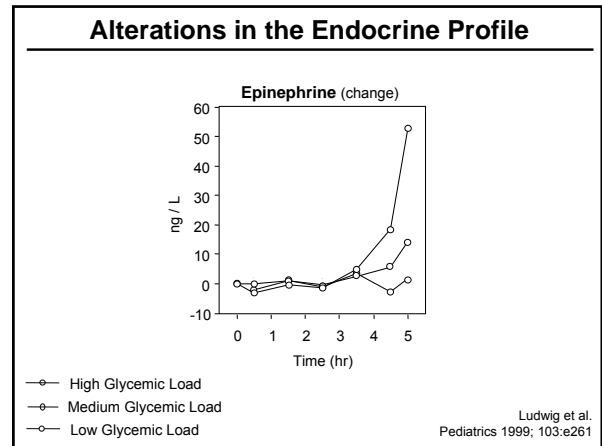
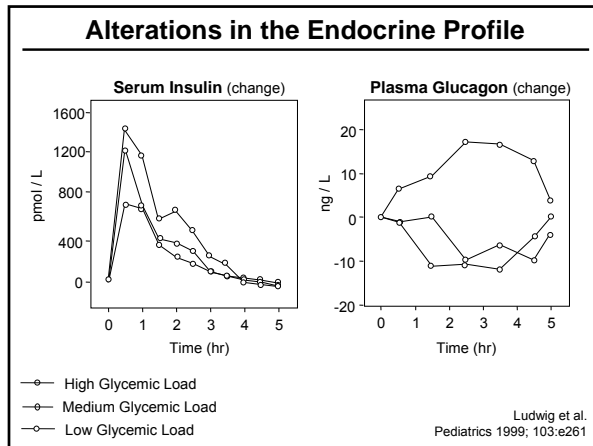


Ebbeling, Ludwig.  
Adv Pediatr 2001;48:179

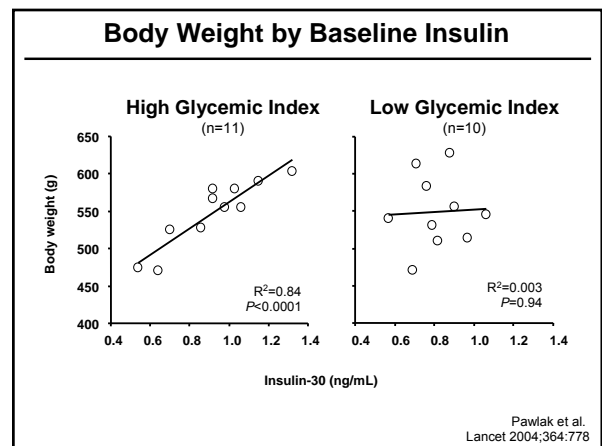
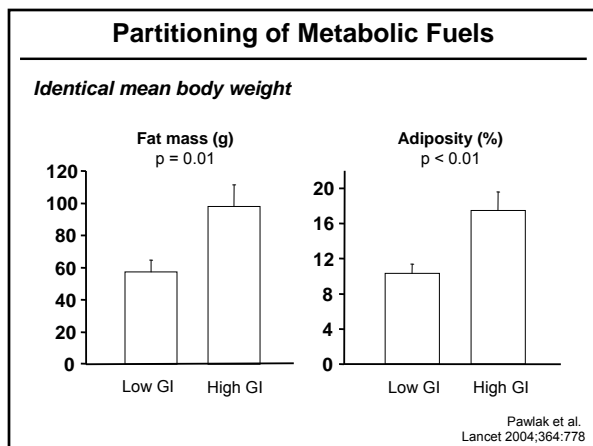
## Alterations in Plasma Glucose



Ludwig et al.  
Pediatrics 1999; 103:e261



- ### Partitioning of Metabolic Fuels
- Effects of glycemic index in a rat model**
- Sprague-Dawley rats with 60% pancreatectomy
  - Fed diets identical in macronutrient composition
    - high GI (high amylopectin starch), n = 11
    - low GI (high amylose starch), n = 10
  - Energy intake controlled to maintain identical mean body weight between groups
  - Body composition measured at 18 weeks using tritiated water
- Pawlak et al. Lancet 2004;364:778



## Partitioning of Metabolic Fuels

### Conclusions

- Glycemic index as an independent factor can affect adiposity, even when controlling for body weight
- Effects of a high GI diet may be greatest in individuals who secrete the most insulin in response to carbohydrate

*More about insulin response in a few minutes...*

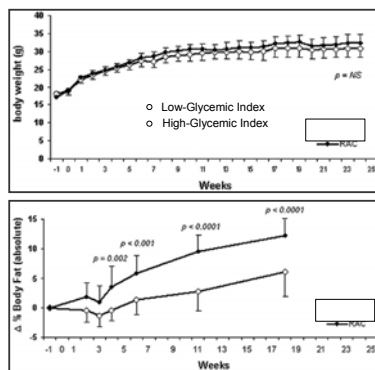
Pawlak et al.  
Lancet 2004;364:778

## Partitioning of Metabolic Fuels

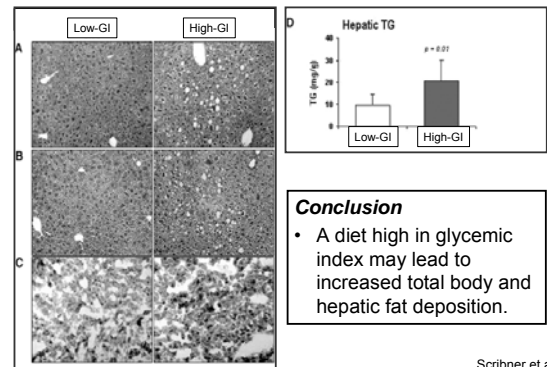
### Effects of glycemic index in a mouse model

- Male 129S2/vPas mice
- Fed diets identical in macronutrient composition for 25 weeks
  - high GI (high amylopectin starch), n = 8
  - low GI (high amylose starch), n = 7
- No difference in total energy intake between groups with *ad libitum* feeding
- Body composition measured by DXA

Scribner et al.  
Obesity 2007; 15: 2190

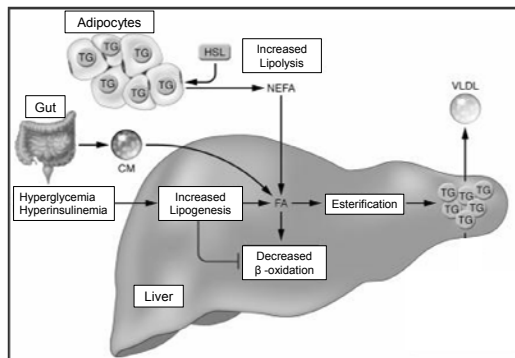


Copyright restrictions may apply. Scribner et al. Obesity 2007; 15: 2190



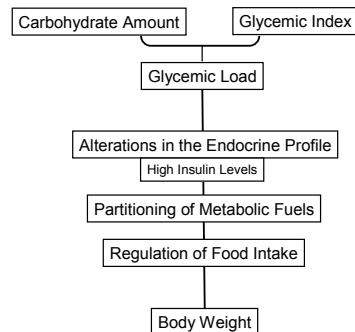
**Conclusion**  
• A diet high in glycemic index may lead to increased total body and hepatic fat deposition.

Copyright restrictions may apply. Scribner et al. Obesity 2007; 15: 2190



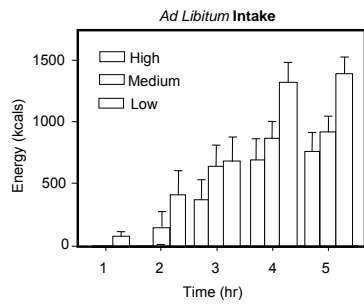
Copyright restrictions may apply. Postic, Girard. J Clin Invest. 2008; 118: 829

## Physiologic Mechanisms



Ebbeling, Ludwig. Adv Pediatr 2001;48:179

## Regulation of Food Intake



Ludwig et al.  
Pediatrics 1999; 103:e261

## Regulation of Food Intake

- Low- vs. high-glycemic load breakfasts (preadolescent children)

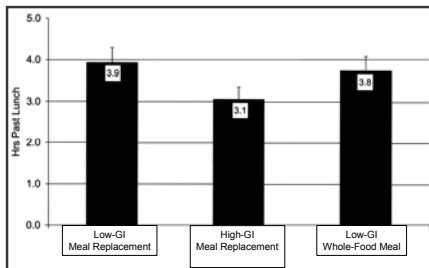
	Low	High
Energy	363	359
Composition	60% carbohydrate 15% protein 25% fat	75% carbohydrate 10% protein 15% fat

- Ad libitum* lunch intake

-145 ± 54 kcal (following low- vs. high-glycemic load breakfasts)

Warren et al.  
Pediatrics 2003;112:e414

## Prolongation of Satiety

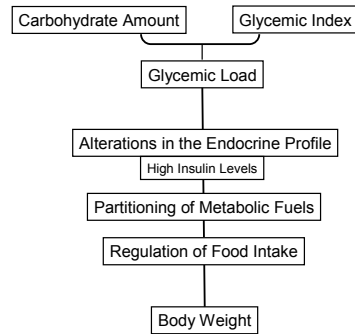


Ball et al. Pediatrics 2003;111:488

Copyright ©2003 American Academy of Pediatrics

PEDIATRICS

## Physiologic Mechanisms



Ebbeling, Ludwig.  
Adv Pediatr 2001;48:179

## Presentation Overview

### Question #1

- How are foods classified using the principles of glycemic index and glycemic load?

### Question #2

- What is the proposed physiological mechanism linking glycemic index and glycemic load with body weight?

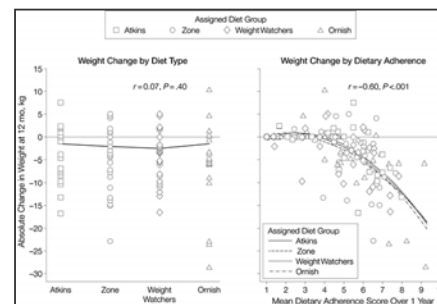
### Question #3

- Why is there inconsistency among intervention studies designed to compare diets that differ in glycemic index and glycemic load?

### Question #4

- What are the practical considerations for prescribing a diet that is low in glycemic index and glycemic load?

## One-Year Changes in Body Weight as a Function of Diet Group and Dietary Adherence Level for All Study Participants



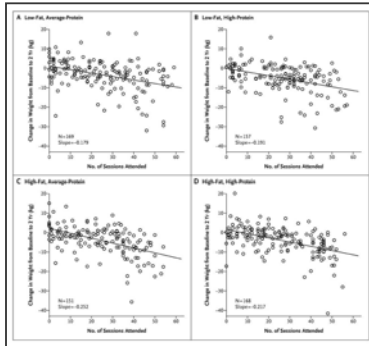
Dansinger et al. JAMA 2005;293:43-53.

Copyright restrictions may apply.

JAMA

### Change in Body Weight According to Attendance at Counseling Sessions for Weight Loss

65% Carb  
20% Fat  
15% Protein



55% Carb  
20% Fat  
25% Protein

Copyright restrictions may apply.

Sacks et al. N Engl J Med 2009; 360:859.

### Inconsistency in Literature

- Motivational and Behavioral Factors (Participant Adherence)
- Variable Treatment Fidelity
- Biological Differences Among Study Participants

### Treatment Fidelity

- Adherence of dietitian (not participants) to study protocols
- **Integrity**: degree to which an intervention is implemented according to established protocols
- **Differentiation**: extent to which treatment conditions are distinct from one another, permitting rigorous testing of study hypotheses related to manipulation of the independent variable (e.g., diet composition, glycemic load)

*Examples in a few minutes...*

Moncher, Prinz.  
Clin Psychol Rev 1991;11:247

### Biological Differences Among Participants

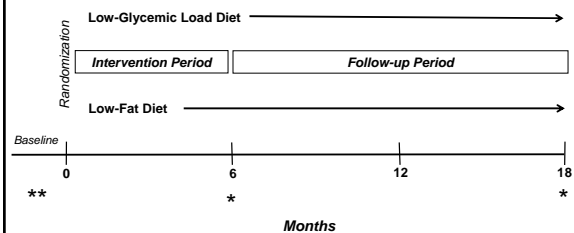
- One physiological mechanism that might relate weight loss to dietary composition is individual differences in the insulin response to carbohydrate consumption.
- Individuals with a high insulin response to oral glucose may be most sensitive to the effects of dietary glycemic load.

### 18-month Randomized Controlled Trial

- Young adults (N=73).
- Purpose. To determine whether insulin response to carbohydrate consumption affects body weight and blood lipids among obese individuals consuming a self-prepared low-glycemic load vs. low-fat diet.
- To reduce the possibility of experimental bias, we aimed to keep treatment intensity, treatment fidelity, nutrition education and dietary counseling strategies, and physical activity prescription the same between diet groups.

Ebbeling et al.  
JAMA 2007;297:2092

### Timeline



\* Insulin-30 (insulin level 30 minutes following standard 75-gram oral glucose load)

\* Body Weight and Blood Lipids

Ebbeling et al.  
JAMA 2007;297:2092

## Diet Prescriptions

	Low-Glycemic Load	Low-Fat
Carbohydrate	40% of energy	55% of energy
Glycemic Index	Low	Prevailing
Fat	35% of energy	20% of energy
Protein	25% of energy	25% of energy
Physical Activity	Based on public health guidelines (emphasis on frequency and duration rather than intensity)	
Nutrition Education Behavioral Counseling	Principles of non-formal adult education and participant-centered counseling "Eat when you are hungry, before you become famished. Stop eating when you are satisfied, before you become stuffed."	

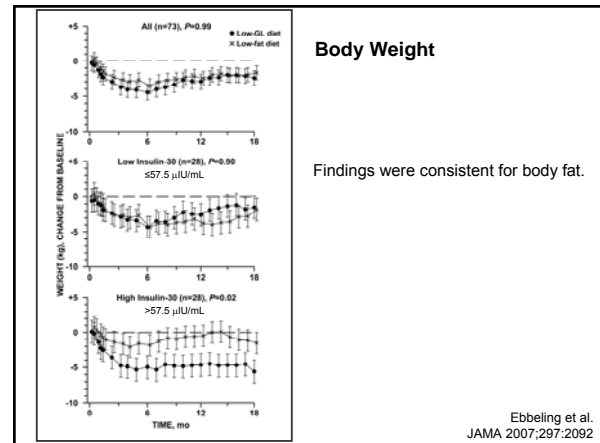
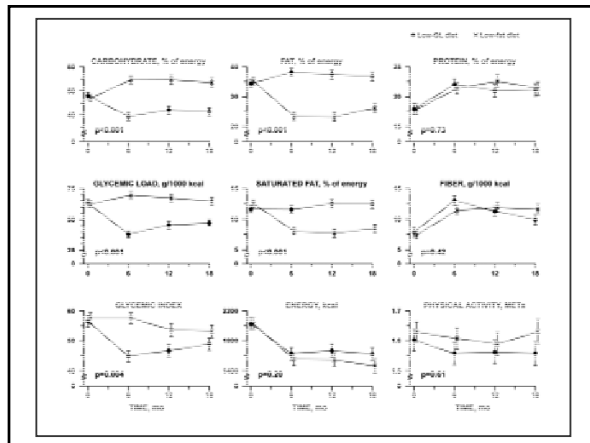
Ebbeling et al.  
JAMA 2007;297:2092

## Treatment Fidelity

### Operationalizing the Concept

- Scripts for 23 group workshops and written educational materials to ensure delivery of well-defined nutrition messages.  
*Examples in a few minutes...*
- Flowcharts to 1) provide structure for a private session and 5 motivational telephone calls and 2) foster dietitian adherence to a participant-centered counseling model.
- Digital recording of the private session and motivational telephone calls.
- Weekly staff meetings to discuss intervention delivery, particularly strategies for assisting individual participants without compromising differentiation between diets.
- Detailed guidelines for providing written feedback to participants on food diaries to avoid unintended overlap in dietary advice between groups.

Ebbeling et al.  
JAMA 2007;297:2092



## Body Weight

Findings were consistent for body fat.

Ebbeling et al.  
JAMA 2007;297:2092

## Blood Lipids

Variable	6 months – Baseline			18 months – Baseline		
	Low-Glycemic Load Diet	Low-Fat Diet	p	Low-Glycemic Load Diet	Low-Fat Diet	p
LDL Cholesterol (mg/dL)	-5.8 (3.4)	-16.3 (3.3)	0.03	-0.3 (3.4)	-10.6 (3.3)	0.03
HDL Cholesterol (mg/dL)	1.6 (1.4)	-4.4 (1.3)	0.002	-3.7 (1.5)	-8.2 (1.5)	0.03
Triglycerides (%)	-21.2 (4.7)	-4.0 (5.6)	0.02	-9.0 (5.4)	2.0 (6.0)	0.18

Ebbeling et al.  
JAMA 2007;297:2092

## Conclusions

- Inconsistency among dietary weight loss trials may be partially due to differences in insulin response to oral glucose.
- Reducing glycemic load may be especially important to achieve weight loss among individuals with a high insulin secretion.
- Regardless of insulin secretion, a low-glycemic load diet has beneficial effects on HDL-cholesterol and triglyceride concentrations but not on LDL-cholesterol concentration.

Ebbeling et al.  
JAMA 2007;297:2092

## Presentation Overview

### Question #1

- How are foods classified using the principles of glycemic index and glycemic load?

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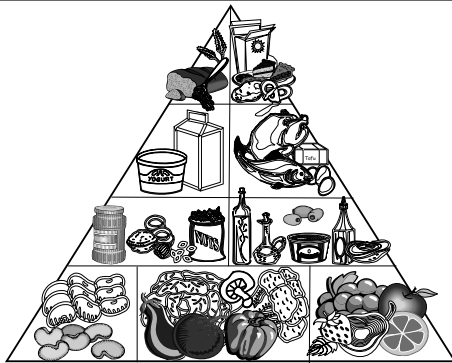
### Question #4

- What are the practical considerations for prescribing a diet that is low in glycemic index and glycemic load?

### Related Research Question

- How is treatment fidelity achieved when comparing diets in randomized controlled trials? (*Differentiation*)

## Low-Glycemic Load Pyramid

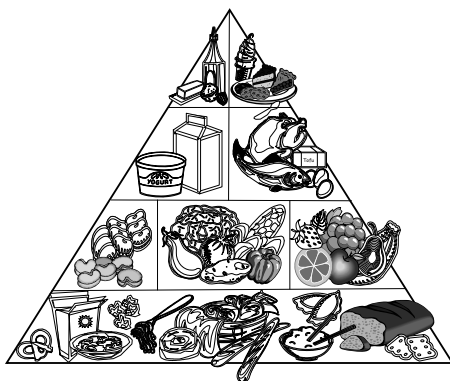


## Main Messages

### Low-Glycemic Load Diet

- Base your diet on non-starchy vegetables, legumes, and fruits on Level 1 of the Pyramid.
- Monitor your intake of foods on Level 4 of the Pyramid. Eat no more than 1-3 servings per day of moderate glycemic load foods. Eat no more than 0-1 serving per day of high glycemic load foods.

## Low-Fat Pyramid



## Main Messages

### Low-Glycemic Load Diet

- Base your diet on non-starchy vegetables, legumes, and fruits on Level 1 of the Pyramid.
- Monitor your intake of foods on Level 4 of the Pyramid. Eat no more than 1-3 servings per day of moderate glycemic load foods. Eat no more than 0-1 serving per day of high glycemic load foods.

### Low-Fat Diet

- Base your diet on low-fat grains, vegetables, fruits, and legumes on Levels 1 and 2 of the Pyramid.
- Monitor your intake of foods on Level 4 of the Pyramid. Eat no more than 1-3 servings per day of added fats. Eat no more than 0-1 serving per day of high-fat sweets and snacks.

Satisfaction				
<i>Practicality</i>				
Question	Descriptor Range	Mean (SEM)		P
		Low-Glycemic Load Diet (n=32)	Low-Fat Diet (n=34)	
• How satisfied are you with this diet?	Not at all satisfied (0) — Extremely satisfied (10)	7.0 (0.4)	6.9 (0.3)	0.80
• How easy has this diet been?	Not at all easy (0) — Extremely easy (10)	5.3 (0.3)	5.1 (0.4)	0.68
• How tasty have the foods been?	Not at all tasty (0) — Extremely tasty (10)	6.9 (0.3)	6.8 (0.3)	0.92

Ebbeling et al.  
JAMA 2007;297:2092

Pediatric Feasibility Studies		
Study	Subjects Intervention	Findings
Young et al. Ambulatory Pediatr 2004; 4: 28 (United States)	<ul style="list-style-type: none"> <li>Ages 5-12 years</li> <li>N=34 enrolled</li> <li>Primary care</li> <li>12 weeks</li> </ul>	<ul style="list-style-type: none"> <li>15 children completed the study</li> <li>14 children achieved a decrease in dietary glycemic index and total carbohydrate intake</li> <li>BMI Z-score decreased in 12 of 15 children</li> </ul>
Fajcsak et al. J Am Coll Nutr 2008; 27: 12 (Hungary)	<ul style="list-style-type: none"> <li>Aged 11.1 ± 1.1 years</li> <li>N=9 enrolled</li> <li>6 weeks</li> </ul>	<ul style="list-style-type: none"> <li>8 children completed the study</li> <li>Children described the diet as "easy to understand"</li> <li>No change in BMI</li> </ul>

**Recommendations for Treatment**

*Notable Quote*

"An emerging body of literature suggests that a focus on the macronutrient ratio is too simplistic and the quality of dietary carbohydrates and fats is an important consideration. The evidence for children and adolescents does not support any specific macronutrient dietary strategy at this time."

Spear et al.  
Pediatrics 2007; 120: S254

**Recommendations for Treatment**

Food Groups	
Fruits and Vegetables	↑
Fruit Juice	↔
Sugar-sweetened Beverages	↓
Dairy Foods and Calcium	↔
Dietary Fiber - "age + 5" grams	↑

Sources: nonstarchy vegetables, fruits, whole grains, legumes, nuts

Spear et al.  
Pediatrics 2007; 120: S254

**Acknowledgments**

Director, Optimal Weight for Life Program Children's Hospital Boston	David S. Ludwig, MD, PhD
Statistician	Henry A. Feldman, PhD
Nutritionists	Margaret M. Lovesky, RD Linda G. Seger-Shippee, DT Michael M. Leidig, RD Niki Philippas, RD
Animal Studies	Dorota B. Pawlak, PhD Kelly B. Scribner, PhD
Research Coordinator	Erica Garcia-Lago, BA
Administrator	Meredith Beard, BS

