OXFORD BROOKES UNIVERSITY

School of Biological and Molecular Sciences

Glycaemic index in health and well-being – current trends and future directions

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Topics to be covered

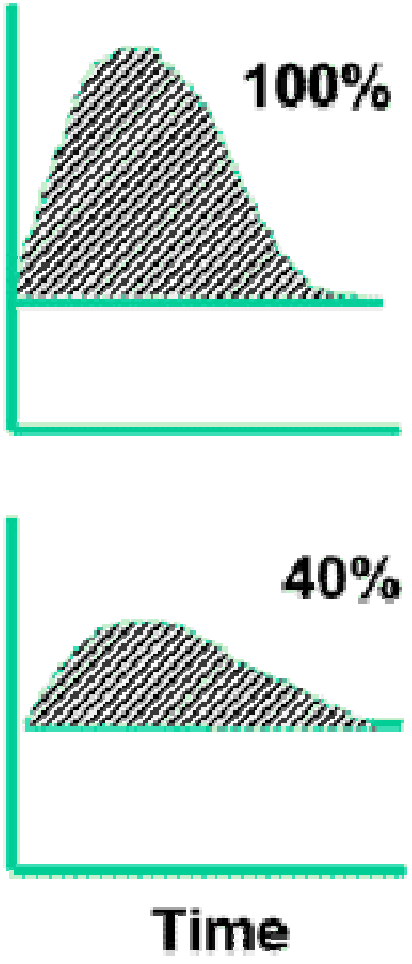
- Application of glycaemic index (GI) in health and well-being
  - Energy balance/obesity
  - Diabetes
  - Blood lipids/cardiovascular disease
- Concept of GI
- The future of GI

Glycaemic index

- The glycaemic index (GI) is a method of ranking foods on a scale according to the extent to which foods raise blood glucose levels after ingestion
- Carbohydrate foods that break down quickly during digestion have the highest GI values - their blood glucose response is fast and high
- Carbohydrates which break down slowly, releasing glucose gradually into the bloodstream, have low GI factors

What is the glycemic index?

- A ranking of food carbohydrates
  - Based on the incremental area under the blood glucose curve
- Comparing equal amounts of carbohydrate
  - Reference food: glucose or white bread

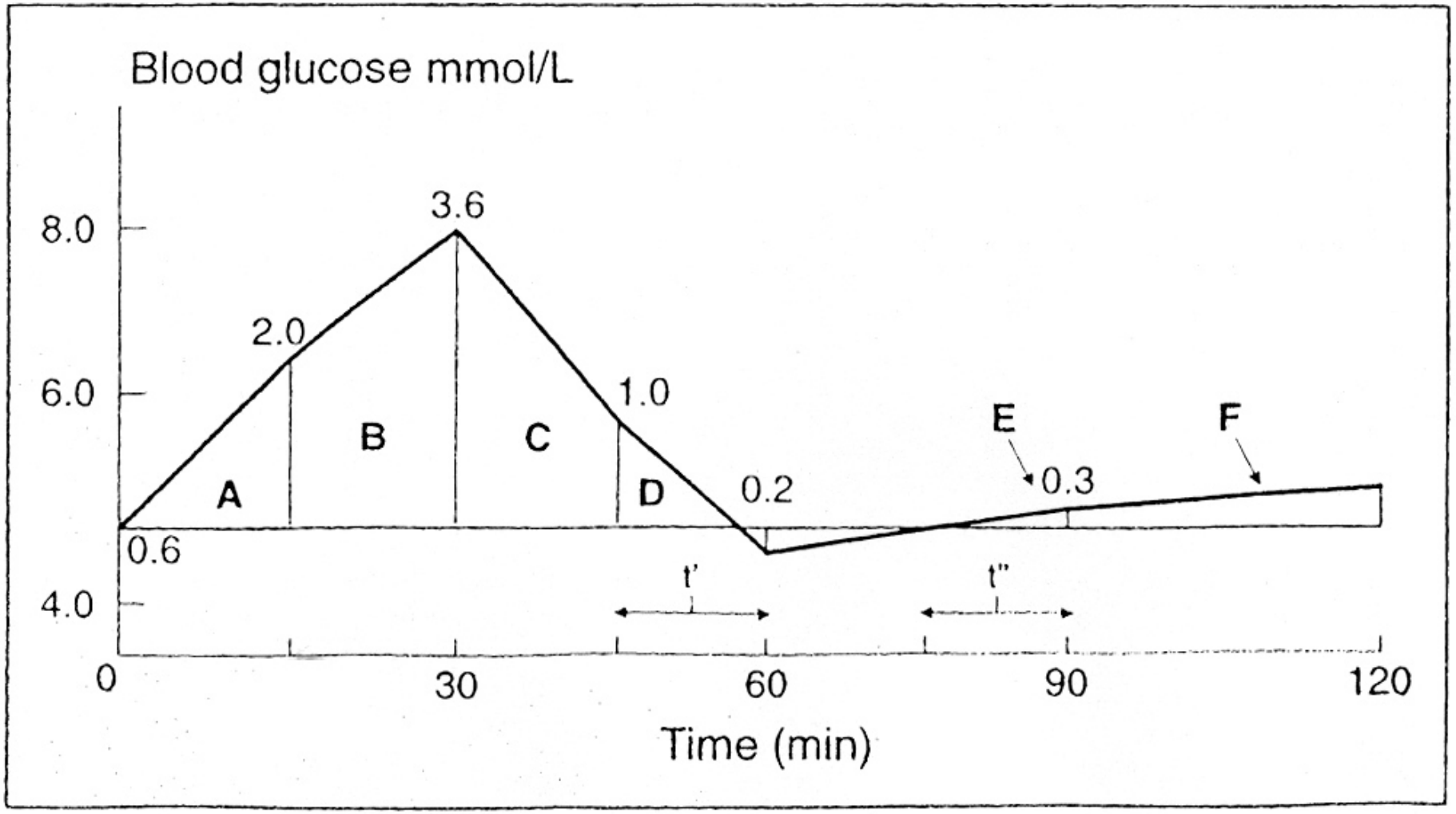


The two hour blood sugar response of a high-GI food (white bread, GI score = 100%) vs a low-GI food (lentils, GI score = 40%)

GI calculation

$$\text{GI of a food} = \frac{\text{Incremental area under the blood glucose response curve for the test food containing 50 g available carbohydrate}}{\text{Corresponding area after equi-carbohydrate portion of a standard food}} \times 100$$

Schematic diagram for the calculation of GI



GI testing of foods

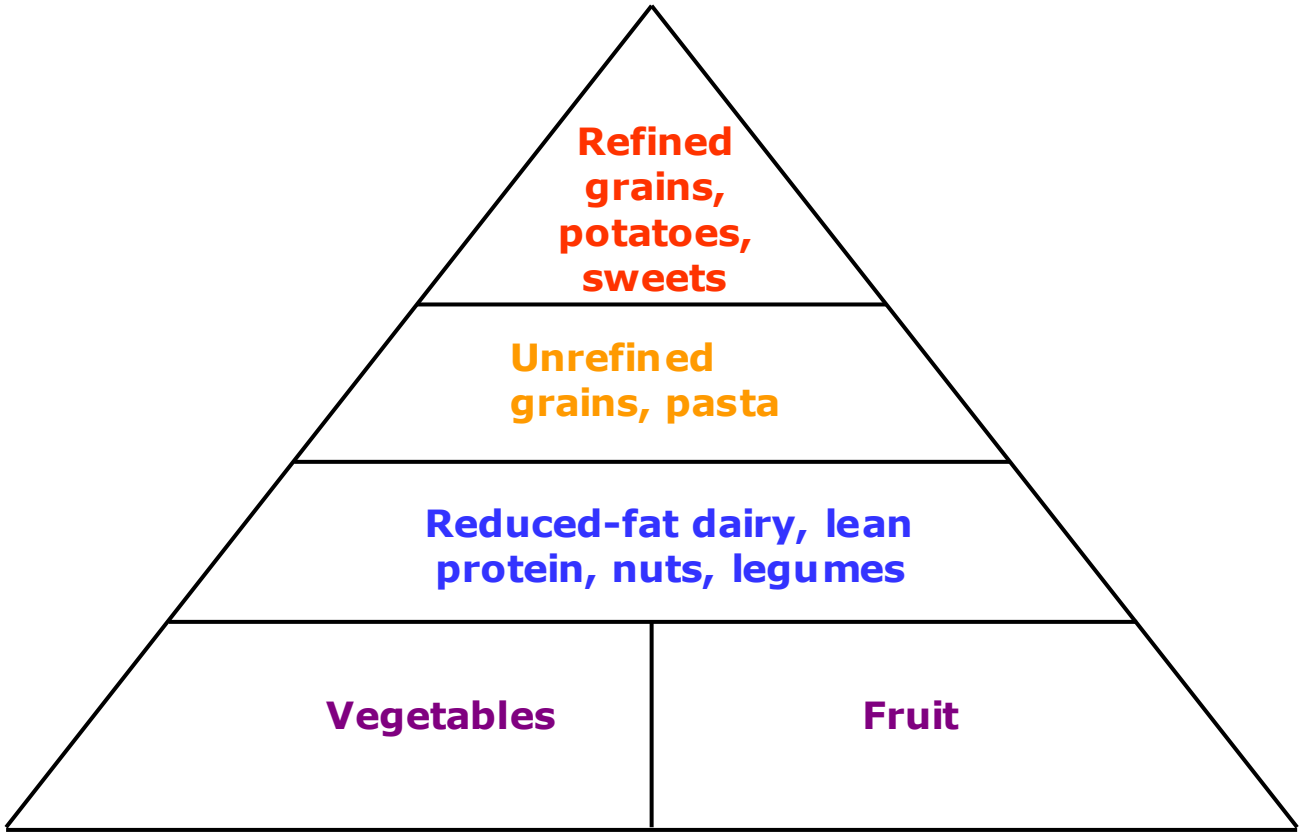
- FAO/WHO* protocol
- The GI rating of a food must be tested physiologically in recognised laboratories
- Only a few nutrition research groups around the world currently provide a legitimate testing service
- Oxford Brookes University is working with Tesco to study the effects of low- and high-GI foods and to develop products that have lower GI ratings
- Tesco have commissioned Oxford Brookes University to develop QC for GI testing

(*FAO/WHO. *Carbohydrates in Human Nutrition*. 1998)

Classification

- Low GI 55 or less
- Medium GI 56-69 inclusive
- High GI 70 or more

GI of foods can be classified simply



Low-, medium- and high-GI foods tested at Oxford Brookes University

Low-GI foods (≤55)

- Bran flakes
- All-Bran
- Pasta
- Lentils
- Butter beans

Medium-GI foods (56-69)

- Wholemeal pitta bread
- Malt loaf
- Muesli
- Fruit & fibre
- Basmati rice

High-GI foods (≥70)

- Corn flakes
- Puffed wheat
- Baked potato
- Fruit loaf
- Instant porridge

GI values of foods - glucose *vs* white bread

Food	GI value (glucose = 100)	GI value (bread = 100)
Lentils	30	42
Apple	36	52
Pasta (spaghetti)	41	59
Baked beans	48	69
White rice (boiled)	50	71
Orange juice	57	74
Croissant	67	96
White bread	70	100
Corn Flakes	84	119

(Foster-Powell *et al*. 2002)

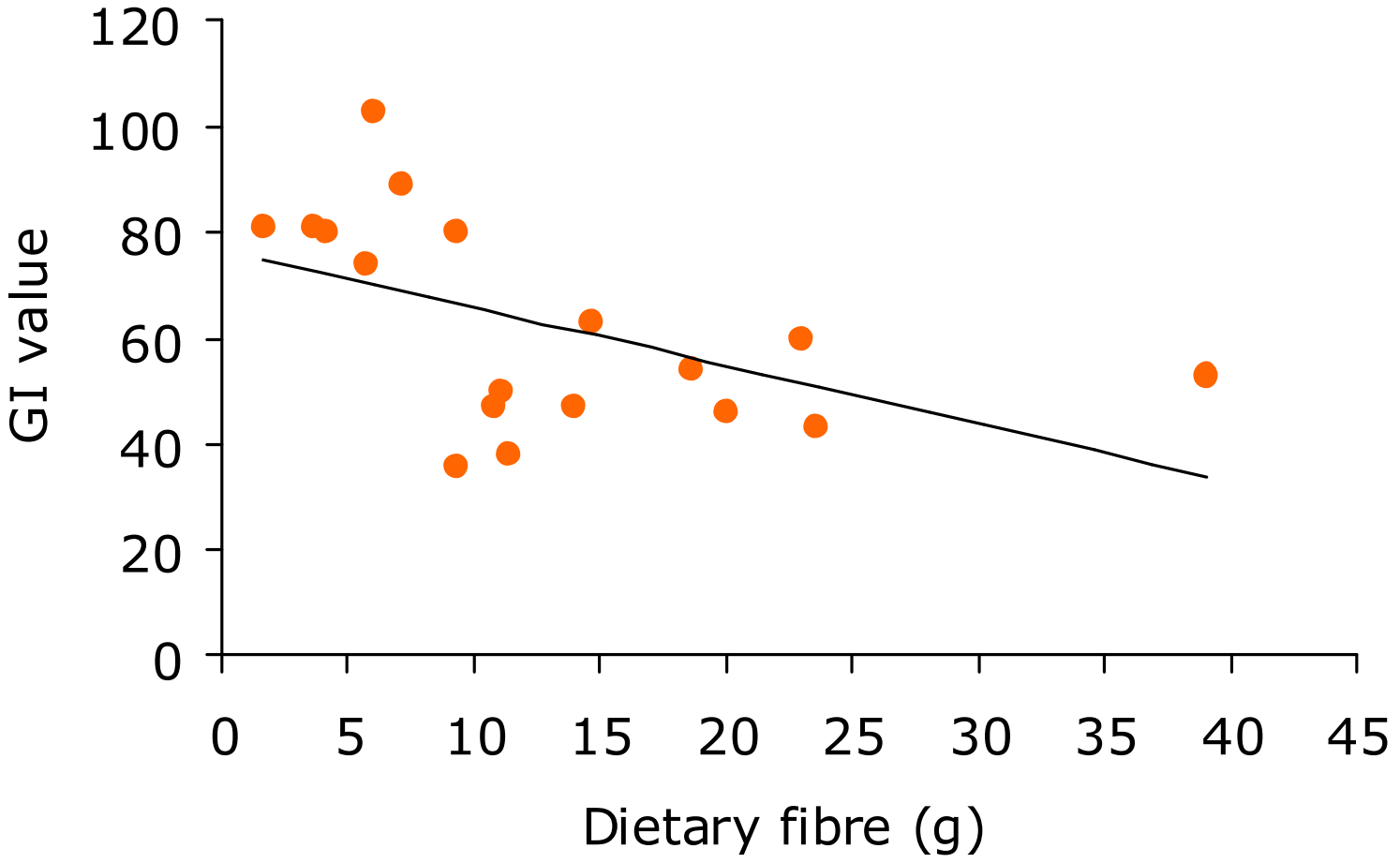
Food factors that influence glycaemic response

- Nature and amount of carbohydrate
- Nature of the monosaccharide components
  - glucose
  - fructose
  - galactose
- Nature of the starch
  - amylose
  - amylopectin
  - starch-nutrient interaction
  - resistant starch
- Cooking or food processing
  - degree of gelatinisation of starch
  - particle size
  - food form
  - cellular structure
- **Other food components**
  - **fat and protein**
  - **dietary fibre**

Food ingredient/macronutrient effect

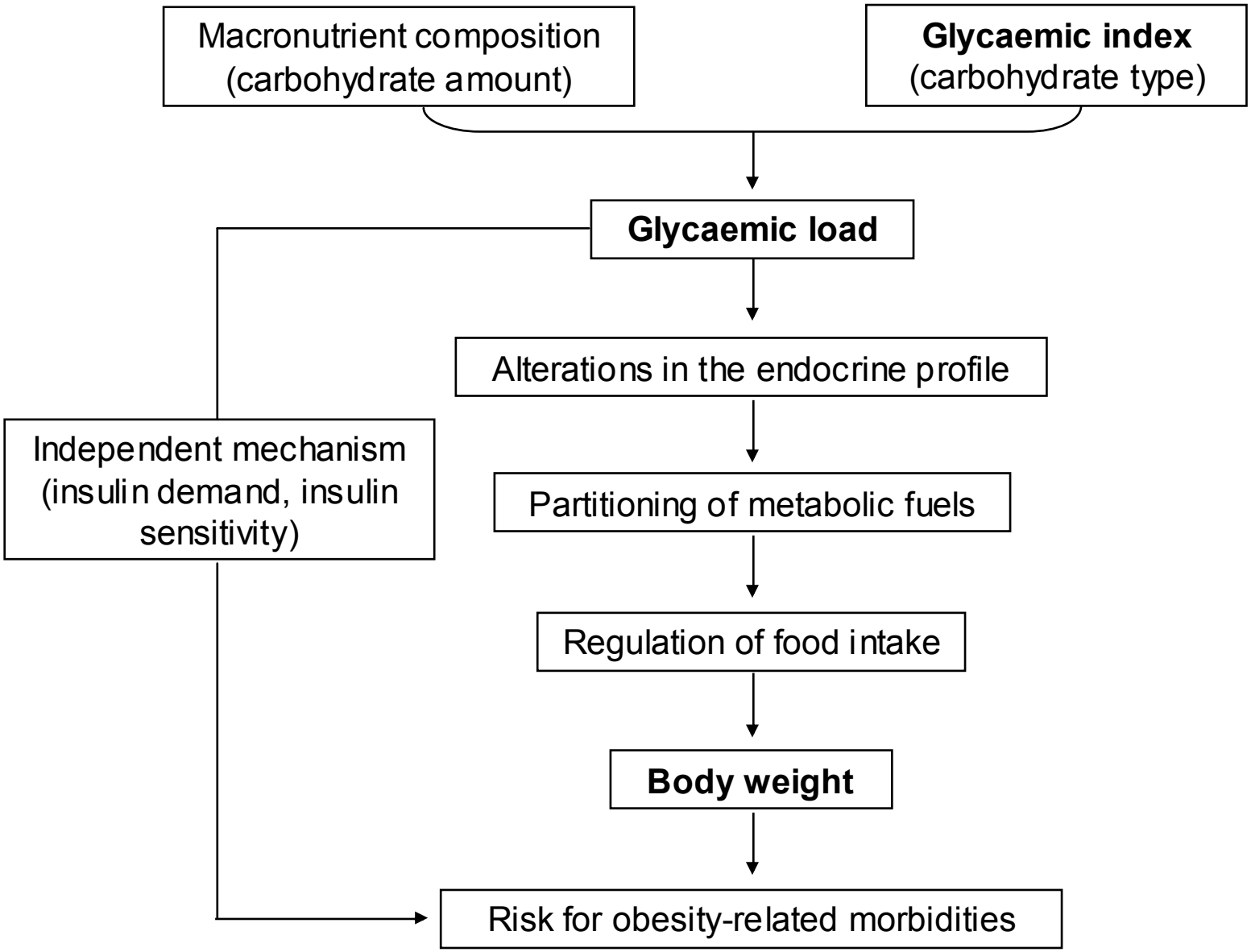
Food	GI value	GI rating
Pasta (white)	55	Low
Pasta (white) with tomato sauce	35	Low
Pasta (white) with tuna	30	Low
Toast (white)	65	Medium
Toast (white) with cheese	35	Low
Toast (white) with baked beans	50	Low

Relationship between GI and dietary fibre



Glycaemic index and obesity

Proposed model linking dietary GI and GL to body weight and obesity-related morbidities



Source: Ebbeling & Ludwig (2001)

Obesity

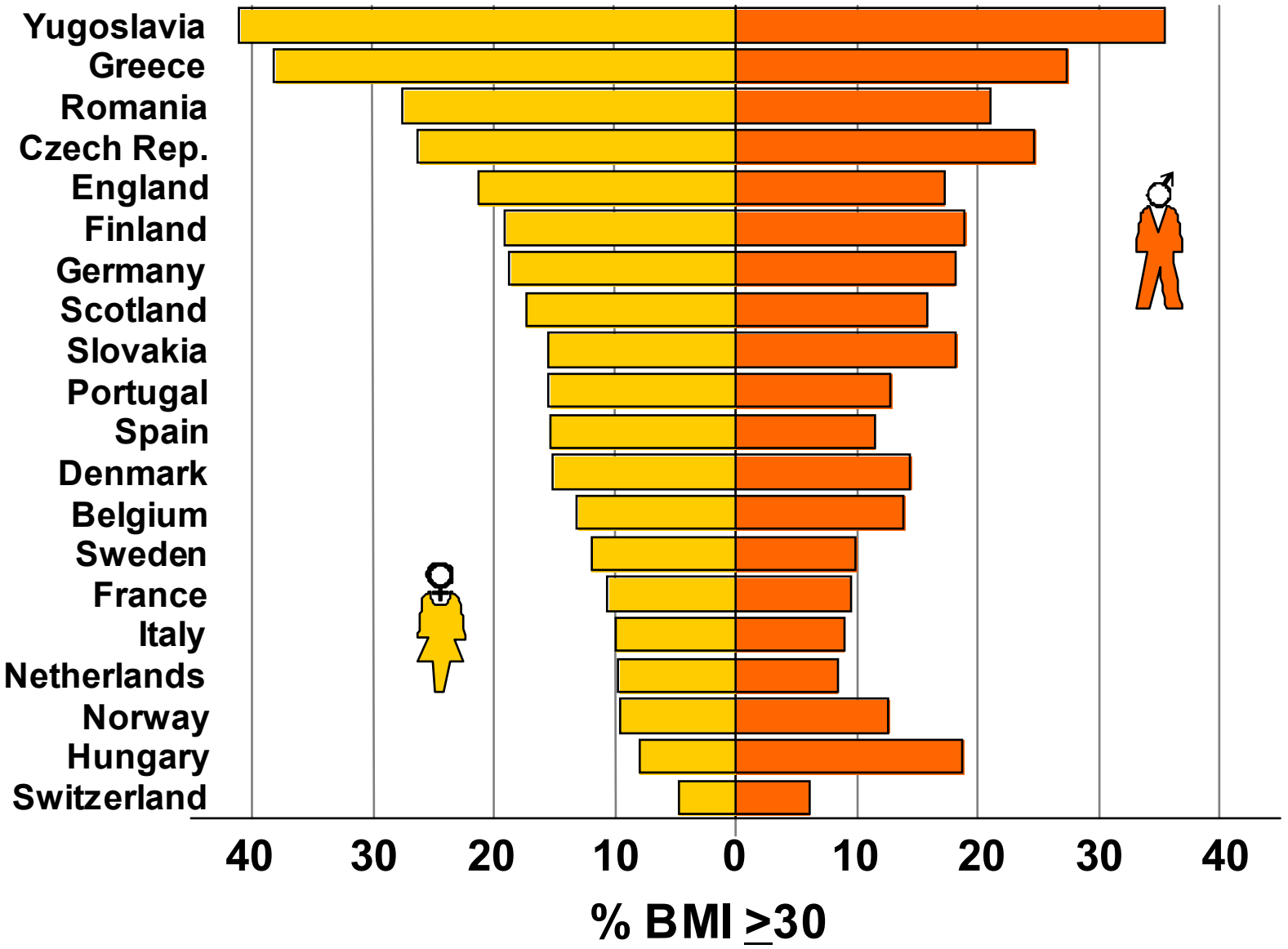
- OBESITY is referred to as an excess accumulation of FAT
- Obesity will result only if you are in POSITIVE ENERGY BALANCE
- Incidence of obesity is greater in women
- 1998 Health Survey:
  - 17.3% men
  - 21.2 % women

Energy balance

Energy balance =
Energy Intake - Energy Expenditure

- You will only be in positive energy balance when energy intake exceeds energy expenditure
- Positive energy balance leads to obesity

Male and female obesity levels in selected European countries



Collated by the IOTF from recent surveys

GI and obesity

- Evidence from short-term feeding studies mainly
- Studies have looked at the effect of GI on hunger and food intake
- Contentious
  - Pawlak *et al*. *Obes Rev* 2002;3:235-43
  - Raben *et al*. *Obes Rev* 2002;3:245-56
- Low GI diets have been used in treatment of obesity (limited data)

GI and obesity

- The effect of GI has been studied in outpatients
  - Significantly more weight loss occurred in a group of obese hyperinsulinaemic women after consuming an energy restricted low-compared to high-GI diet (crossover arm:-7.4 v -4.5kg)
    (Slabber *et al*. *Am J Clin Nutr* 1994;60:48-53)
  - Preliminary data indicated lower adiposity by DEXA scan in 11 obese men after 5 weeks on an energy- and nutrient-controlled low-compared with high-GI diet.
    (Bouché *et al*. *Diabetes* 2000;49;A40-1)

Do low-GI foods reduce food intake at subsequent meals?

Reference	Food	Subjects	Result
Barkeling *et al*. (1995)	Pasta *vs* bread	16 elderly men	No diff
Benini *et al.* (1995)	High *vs* low fibre meal	8 healthy subjects	No (but delayed return of hunger)
Holt & Miller (1995)	Rice (quick cook and varied amylose content)	9 adults	Yes
Stewart *et al*. (1997)	Shredded wheat (SW) + glucose; SW + fructose	13 men	No diff
Riguad *et al*. (1998)	Psyllium fibre in bfast	14 adults	Yes, for rest of day
Kong *et al.* (1999)	75g fructose *vs* glucose	8 healthy males	No diff
Ludwig *et al*. (1999)	Oatmeal type	12 obese teenage boys	Yes, EI ↓ 81%
Ball *et al*. (2003)	Meal replacements	16 adolescents	No diff
Warren *et al*. (2003)	Breakfasts (cereal/bread)	37 preadolescents	Yes

Are low-GI diets effective for weight loss?

Reference	Diet	Subjects	Greater weight loss?
Clapp (1997, 2002)	Low- *vs* high-GI, 24-28 (8 weeks gestation until term)	Healthy pregnant women	**Yes** (high-GI babies also overweight)
Agus *et al*. (2000)	Low- *vs* high-GI diet over 9 days	10 moderately overweight men	**No diff** Greater reduction in leptin
Speith *et al*. (2000)	Ad lib low-GI *vs* hypo-energetic low-fat diet for 1 year	107 obese children	**Yes**
Bouché *et al*. (2002)	Low- *vs* high-GI diet for 5 weeks + crossover	11 men	**No**, but: ↓ in ab fat mass ↑ lean mass trend
Sloth *et al*. (2004)	10-week parallel study	45 overweight women	**No** (but appears to be NS tendency)

Evidence for low-GI foods

- Food intake
  - Low-GI foods reduced food intake at a subsequent meal in 4/9 studies
  - 1/9 studies showed a delayed return of hunger
- Weight loss
  - A low-GI diet produced greater weight loss compared to a high-GI diet in 2/5 studies
  - 1/5 studies showed a decrease in abdominal fat mass
  - 1/5 studies showed a greater decrease in leptin

Controversies

- Many of the studies to date have been short-term single meal effects
- **Some studies have failed to match the macronutrient composition of test meals**
- **Changes in other factors might also influence bodyweight (e.g. fibre content, palatability, energy density)**
- Measures of hunger/satiety are variable
- Some studies have failed to show an effect of low GI on hunger/food intake
- The effect of GI in the context of a mixed meal must be considered

Effects of dietary glycaemic index on adiposity, glucose homoeostasis, and plasma lipids in animals

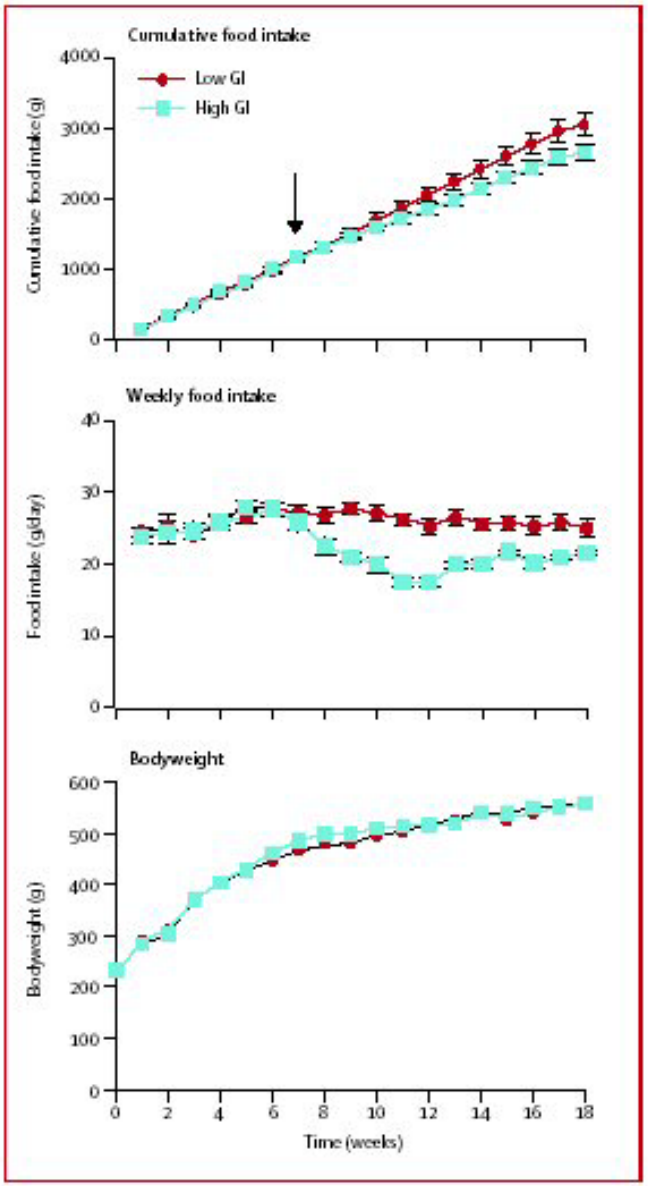
Pawlak DB, Kushner JA & Ludwig DS. *Lancet* 2004;364:778-85

Methods

- Male rats
  - High-GI diet (*n* 11)
  - Low-GI diet (*n* 10)
- Controlled diet to maintain bodyweight between the groups for 18 weeks
- Identical macronutrient composition (69% CHO, 20% protein, 11% fat as percentage total energy)
- Type of starch
  - High-GI 100% amylopectin
  - Low-GI 60% amylose/40% amylopectin

Food intake and bodyweight among rats eating the low-GI and high-GI diets

(Pawlak *et al*. *Lancet* 2004;364: 778-785)



Body composition changes (week 17)

	Mean (SE) in group	
	High-GI	**Low-GI**
Bodyweight (g)	547.9 (13.4)	549.2 (15.2)
Body fat (g)	97.8 (13.6)	57.3 (7.2)
Lean body mass (g)	450.1 (9.6)	491.9 (11.7)
Adiposity (%)	17.5 (2.1)	10.3 (1.1)

(Pawlak *et al*. *Lancet* 2004;364:778-85)

Findings

- Consumption of a high-GI diet per se adversely affects body composition and risk factors for diabetes and cardiovascular disease in animal models
- Adiposity was significantly greater in the high-GI group than in the low-GI group
- At 18 weeks, high-GI animals had more abdominal fat or "central adiposity" compared to the low-GI animals
- Triglyceride concentration was almost three times higher in high-GI than in low-GI group

Glycaemic index and diabetes

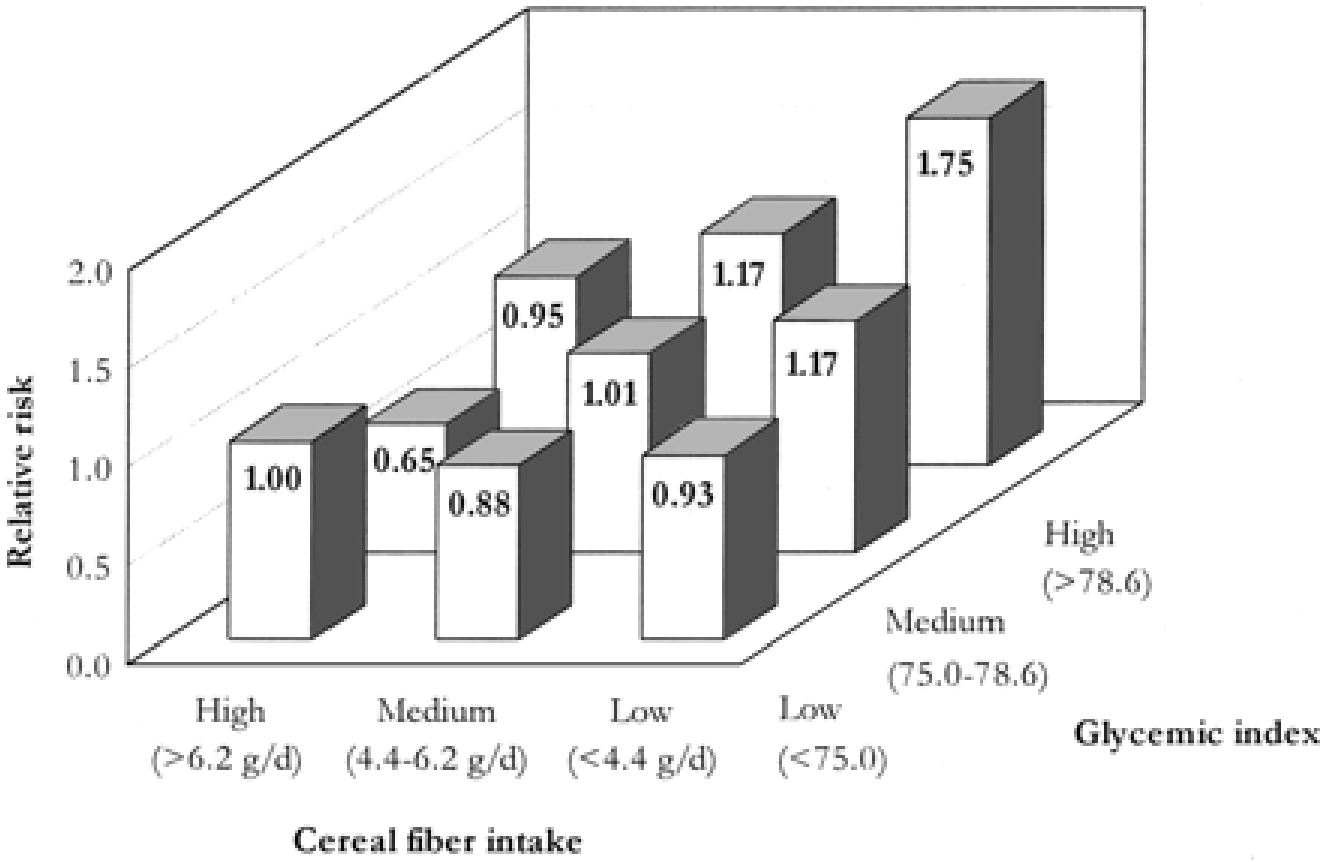
GI and diabetes

- Epidemiological data has linked the risk of diabetes to GI
- A number of study have looked at the effect of low GI on markers of diabetic control

GI and diabetes risk

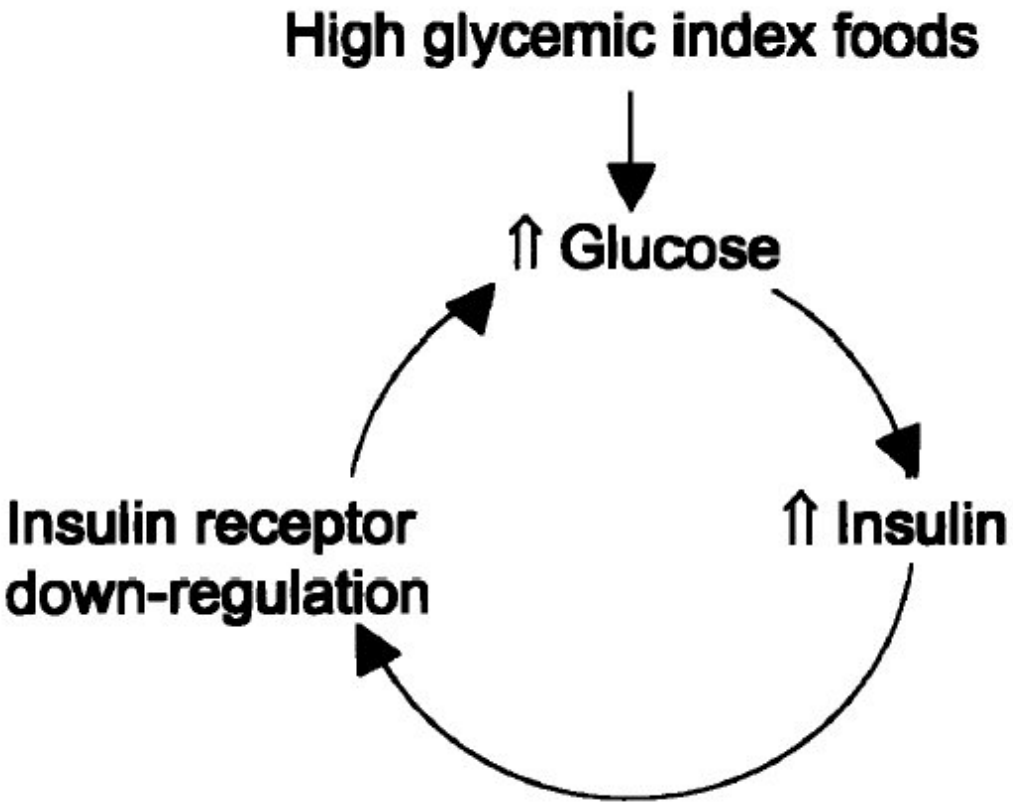
- Observational studies have looked at the association of GI and diabetes
  - Nurses' Health Study (Salmeron *et al*. *JAMA* 1997;277:472-7)
  - Health Professional's Follow–Up Study (Salmeron *et al*. *Diabetes Care* 1997;20:545-50)
- The risk of diabetes was higher among individuals in the highest quintile of GI or GL compared to those in lowest quintile, after adjustment for BMI and other potentially confounding variables
- Iowa Woman's Health Study in contrast did not find similar association (Meyer *et al. Am J Clin Nutr* 2000;71:921-30)

Relative risk of type 2 diabetes by different levels of GI



(Schulze *et al*. *Am J Clin Nutr* 2004;80:348-56)

Potential mechanism for the relationship between high-GI foods and insulin resistance



(Augustin *et al*. *Eur J Clin Nut* 2002;56:1049-71)

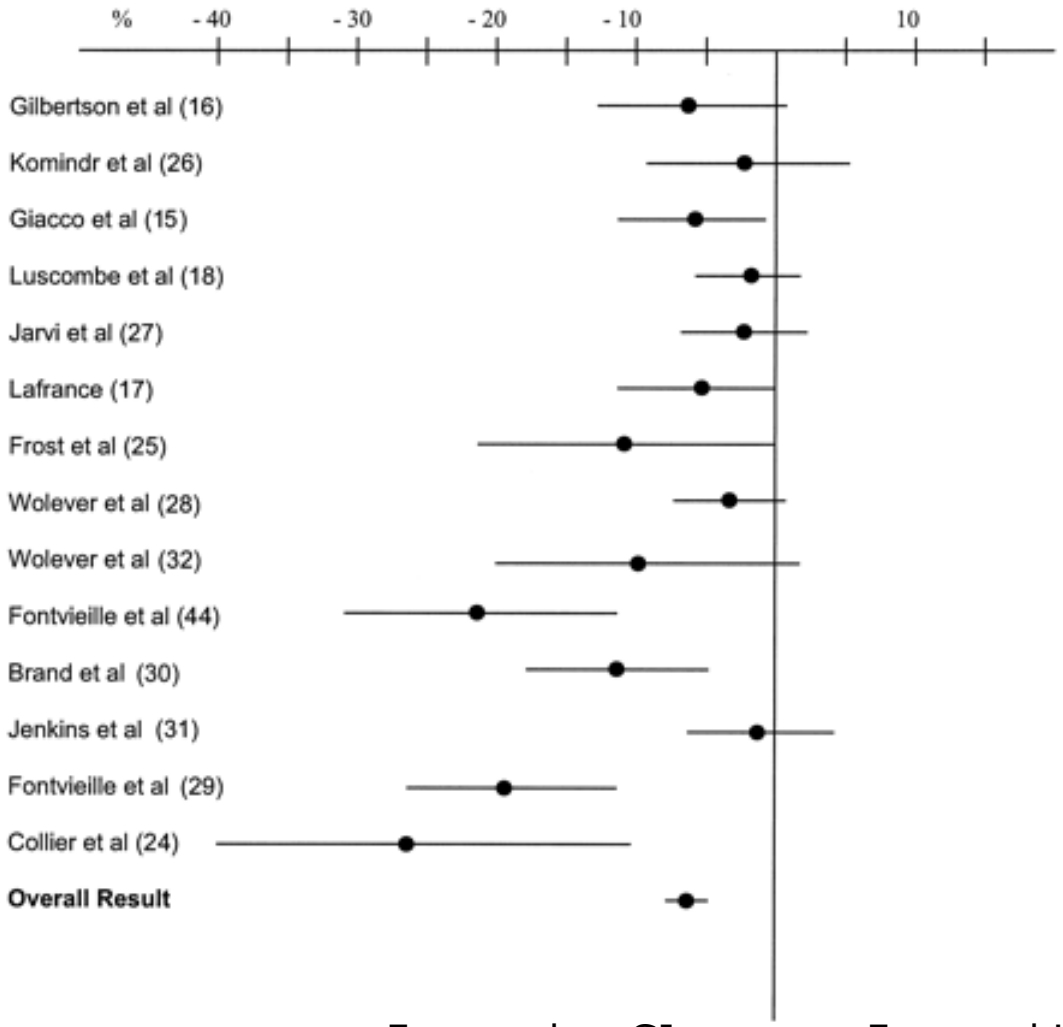
GI in the management of diabetes

- Theoretically, low-GI may improve management by lowering postprandial hyperglycaemia and decreasing the risk of postabsorptive hypoglycaemia
- Variation in international diabetes nutritional guidelines for the role of GI
- American guidelines – GI not recommended
- UK and European guidelines – GI recommended

Low-GI diets in the management of diabetes

- Meta-analysis of randomised controlled trials (Brand-Miller *et al*. *Diabetes Care* 2003;26:2261-7)
- 14 studies included in final analysis (356 subjects)
  - 203 type 1 diabetes
  - 153 type 2 diabetes
- After an average duration of 10 weeks, subjects with type 1 and type 2 diabetes who followed a low-GI diet had lower:
  - HbA_{1c} levels (0.4%)
  - Fructosamine levels (0.2 mmol/l)
- Clinically important reduction in HbA_{1c}

High-GI *vs* low-GI - % change in HbA_{1c} or fructosamine



Effect of low-GI diet on blood glucose control in type 2 diabetes

Subject	Number	Duration (weeks)	Change in diet GI	Change in HbA_{1C} %
Type 2	8	2	-23	-7
Type 2	16	12	-13	-11
Type 1&2	24	4	-5	-3
Type 2	20	3	-31	-6

(Augustin *et al*. *Eur J Clin Nut* 2002;56:1049-71)

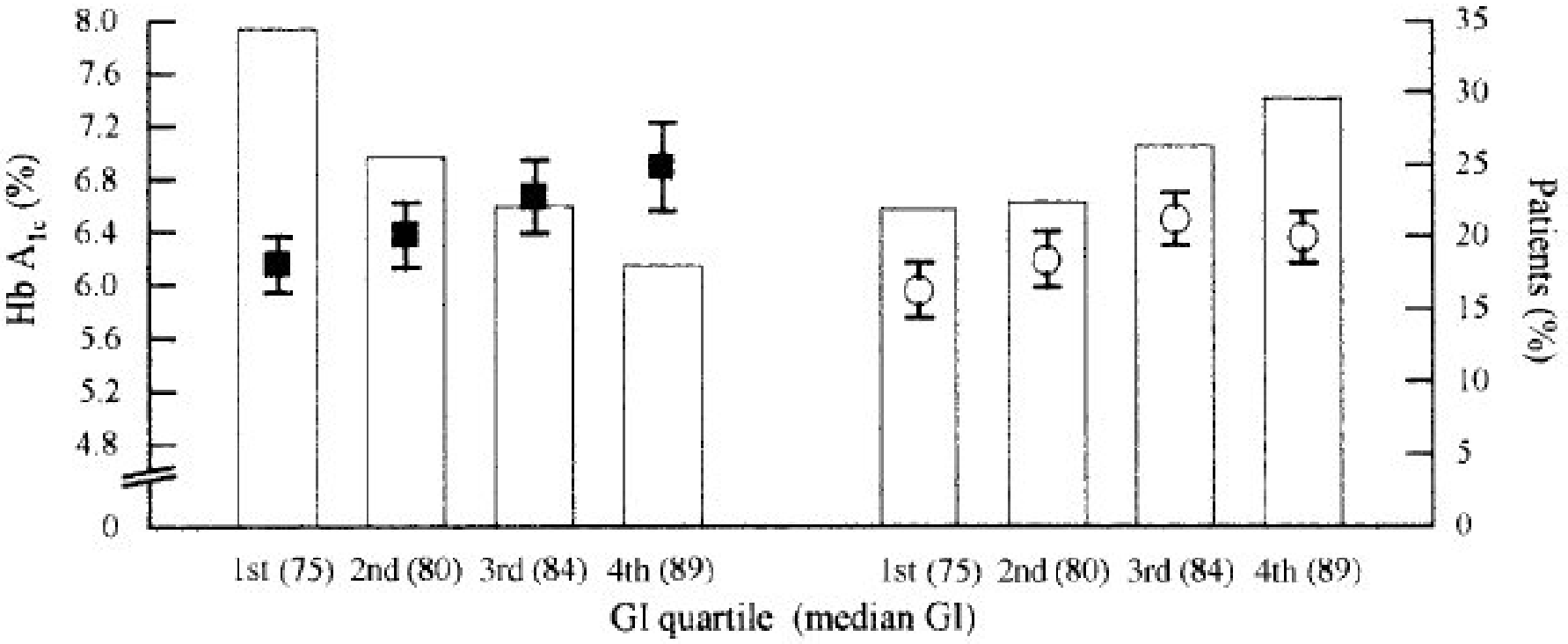
EURODIAB Complications Study

- 31 centres throughout Europe
- 2054 patients with type 1 diabetes
- GI patient's diet positively associated with HbA_{1c}
- HbA_{1c} 11% lower in patients from southern Europe with lowest quartile GI values compared to those in highest quartile
- 6% difference in northern, eastern and western Europe

(Buyken *et al*. *Am J Clin Nutr* 2001;73:574-81)

Mean HbA_{1c} concentrations in relation to quartiles of GI in patients with type 1 diabetes

"A lower dietary GI is related to lower HbA_{1c} concentrations"



(Buyken *et al*. *Am J Clin Nutr* 2001;73:574-81)

Glycaemic index and blood lipids/coronary heart disease

GI and CHD risk

- Some epidemiological evidence suggests that low-GI diets may decrease the risk of CHD
  - Liu *et al*. *Am J Clin Nutr* 2000;71:1455-61
- The risk of CHD was higher among individuals in the highest quintile of GI or GL compared to those in lowest quintile, after adjustment for smoking, age, total energy intake and other CHD risk factors
- The Zutphen Elderly study in contrast did not find a similar association
  - van Dam *et al*. *Eur J Clin Nutr* 2000;54:726-31

Change in lipid profile after a low-GI and a high-GI diet

Reference	Duration	Subjects	Change (mmol/l)	
			Low-GI	High-GI
Frost *et al*. (1996)	4 weeks	11 males (CHD) 12 females (CHD)	TG 0.08 TC -0.70 HDL -0.07 LDL -0.60	TG 0.04 TC -0.33 HDL -0.07 LDL -0.20
Järvi *et al*. (1999)	24 days	15 males - type 2 5 females - type 2	TG -0.55 TC -1.56 HDL -0.18 LDL -1.16	TG -0.58 TC -1.33 HDL -0.19 LDL -0.90
Bouché *et al*. (2002)	5 weeks	11 males	TG -0.09 TC -0.40 HDL 0.03 LDL -0.36	TG 0.04 TC -0.22 HDL 0.00 LDL -0.27
Kabir *et al*. (2002)	4 weeks	13 males - type 2	TG 0.10 TC -0.30	TG -0.20 TC 0.20

TG, triglyceride; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol

Conclusions

- Low-GI diets appear to reduce appetite and food intake
- Low-GI diets reduce glucose peaks in subjects and can help control diabetes (↓ HbA_{1c} levels)
- Low-GI diets are associated with a reduction in triglycerides and total cholesterol
- Inclusion of low GI foods in the diet fits in with current healthy eating recommendations for a diet high in fibre and low in fat

The future

- Further research on GI and energy regulation is required with an emphasis on long-term well controlled study designs
- Studies need to be done in wider population groups including ethnic groups
- A better understanding of the relationship between food structure and physiological response to foods
- The concept of GI may be easily and successfully integrated with other dietary interventions, for example high-protein diets

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