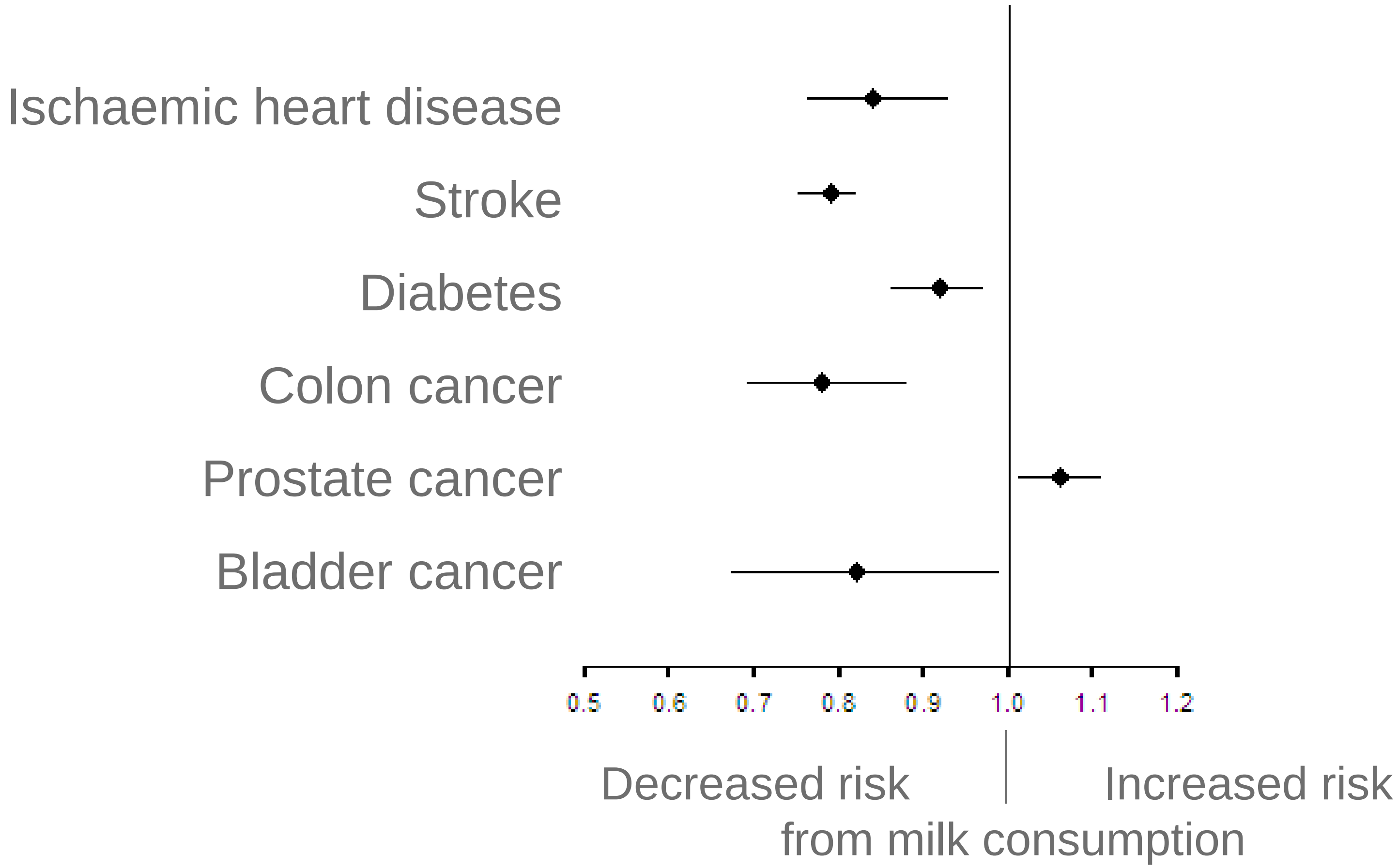
Department of Human Nutrition

# Calcium, Dairy Products and Weight Management


Arne Astrup

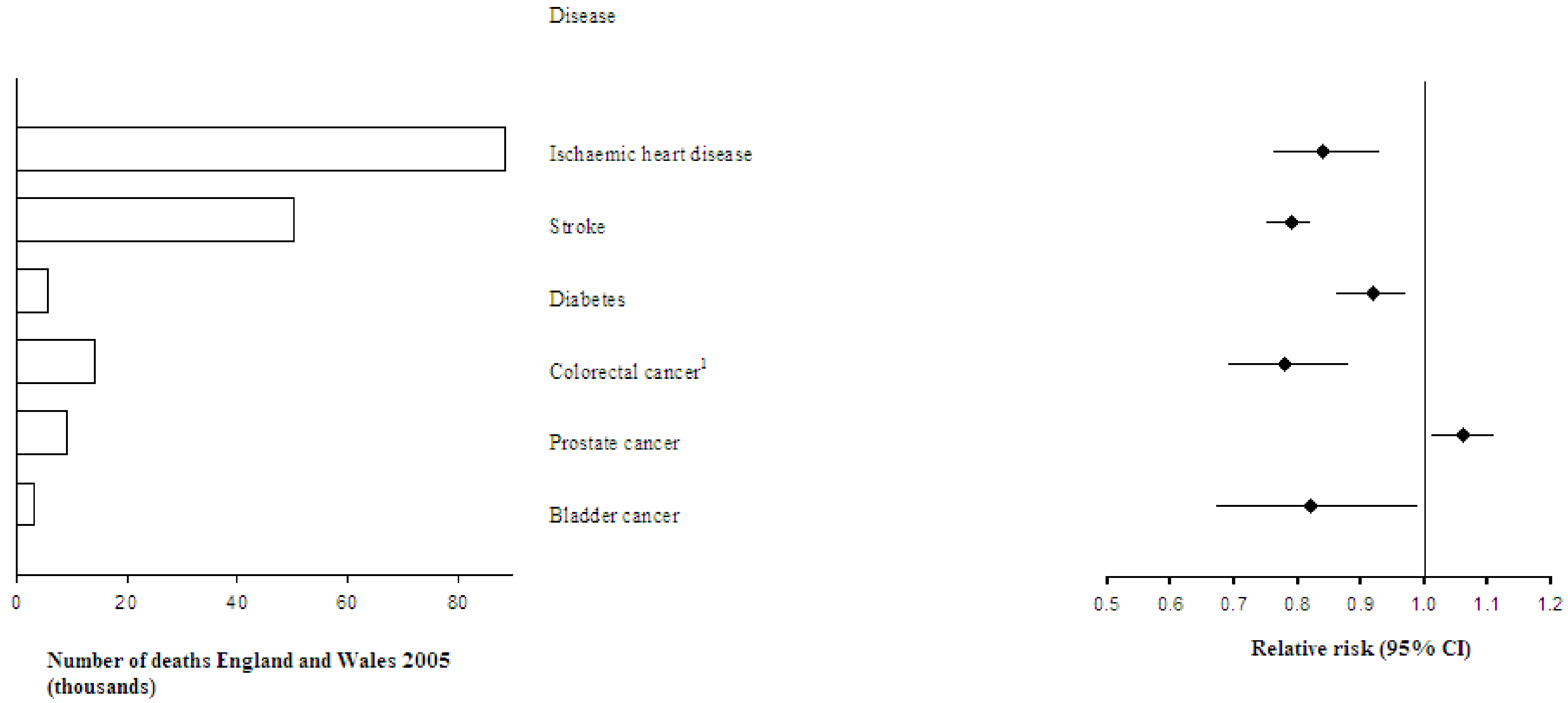
Head, professor, MD, DMSc

# *How does eating dairy products impact health in the long run?*




Elwood P et al. J Amer Coll Nutr. 2008;27:723S-734S

# How does eating dairy products impact health in the long run?



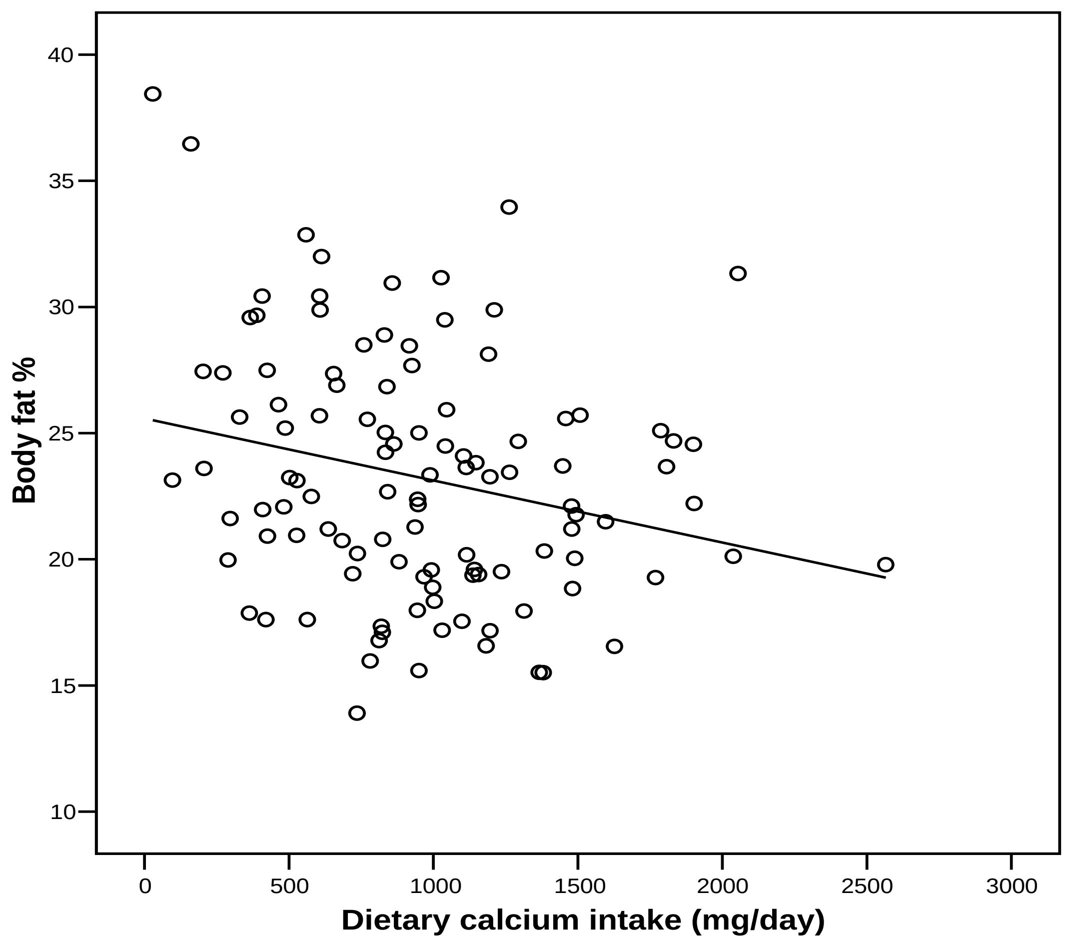

Elwood P et al. J Amer Coll Nutr. 2008;27:723S-734S

Observational studies:

Is the inverse association between dairy intake and body fatness explained by:

Dairy = protein + calcium ?

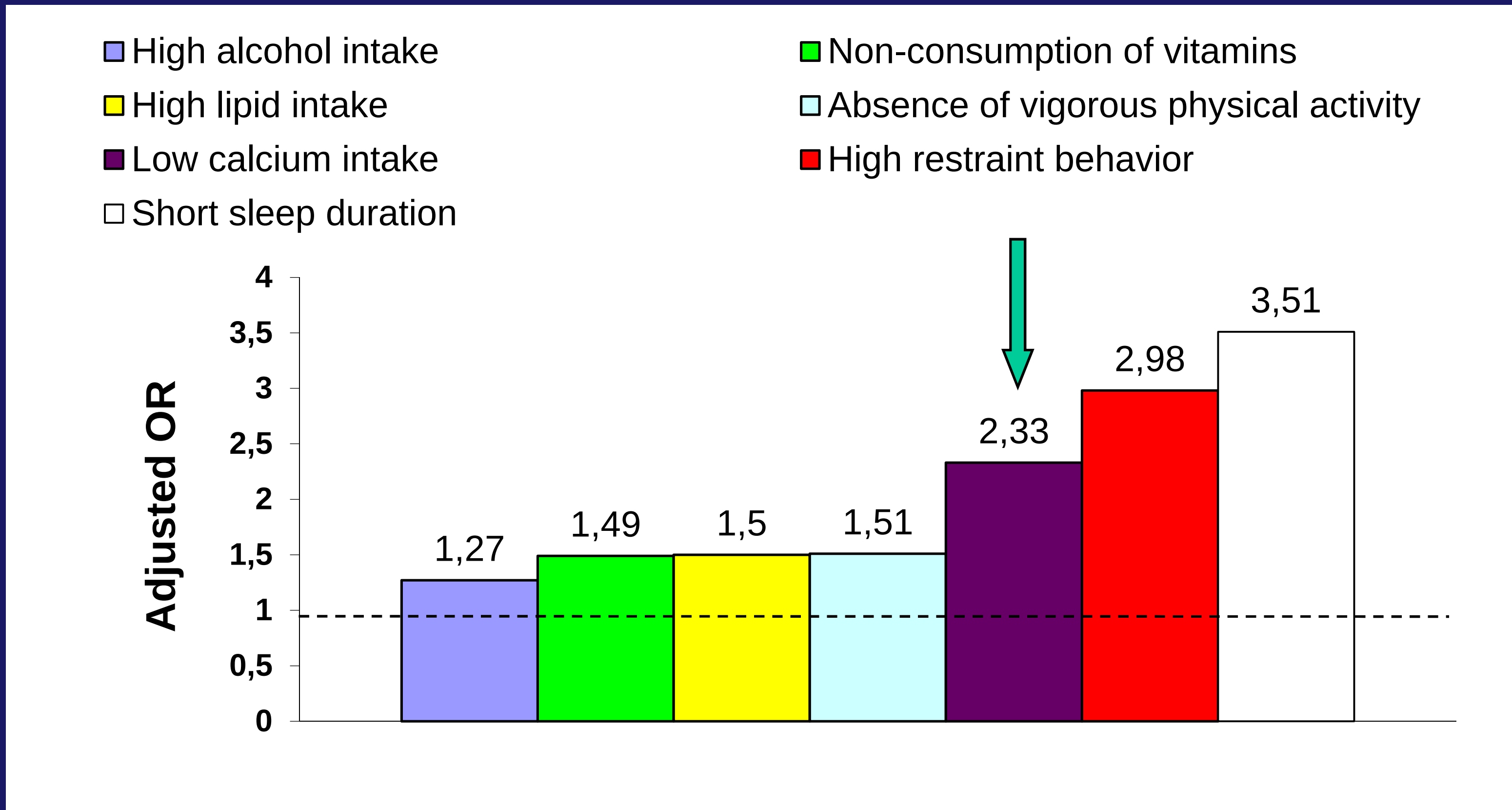
# Effect of habitual calcium intake on body weight and composition




r=-0.242
p=0.011

Lorenzen JK, Astrup A. Am. J. Clin. Nutr. (2006)

# Potential risk factors and adult overweight/obesity: the Quebec Family Study



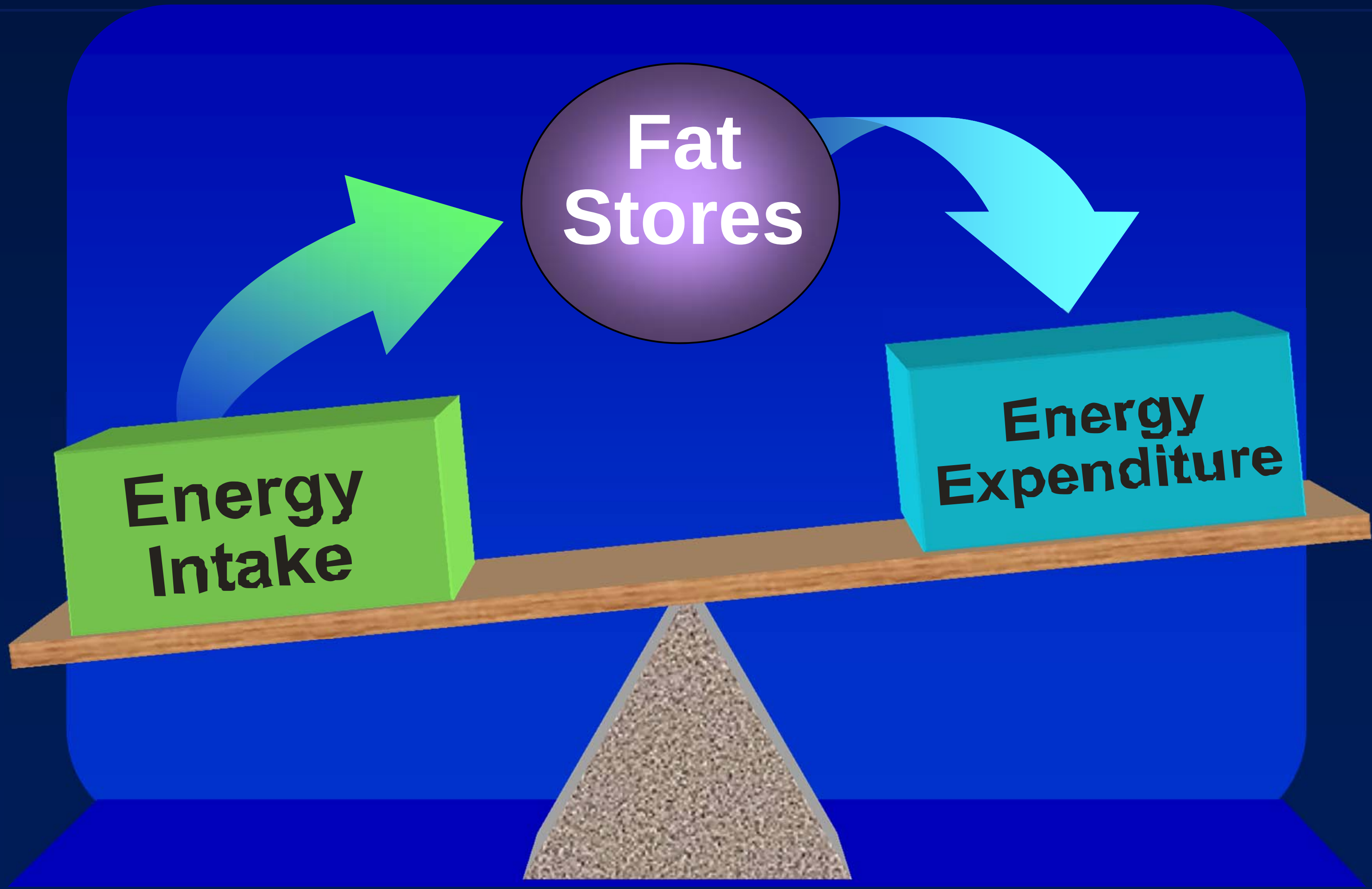

Adjusted for age and sex.

Chaput JP *et al*. Obesity (2008).

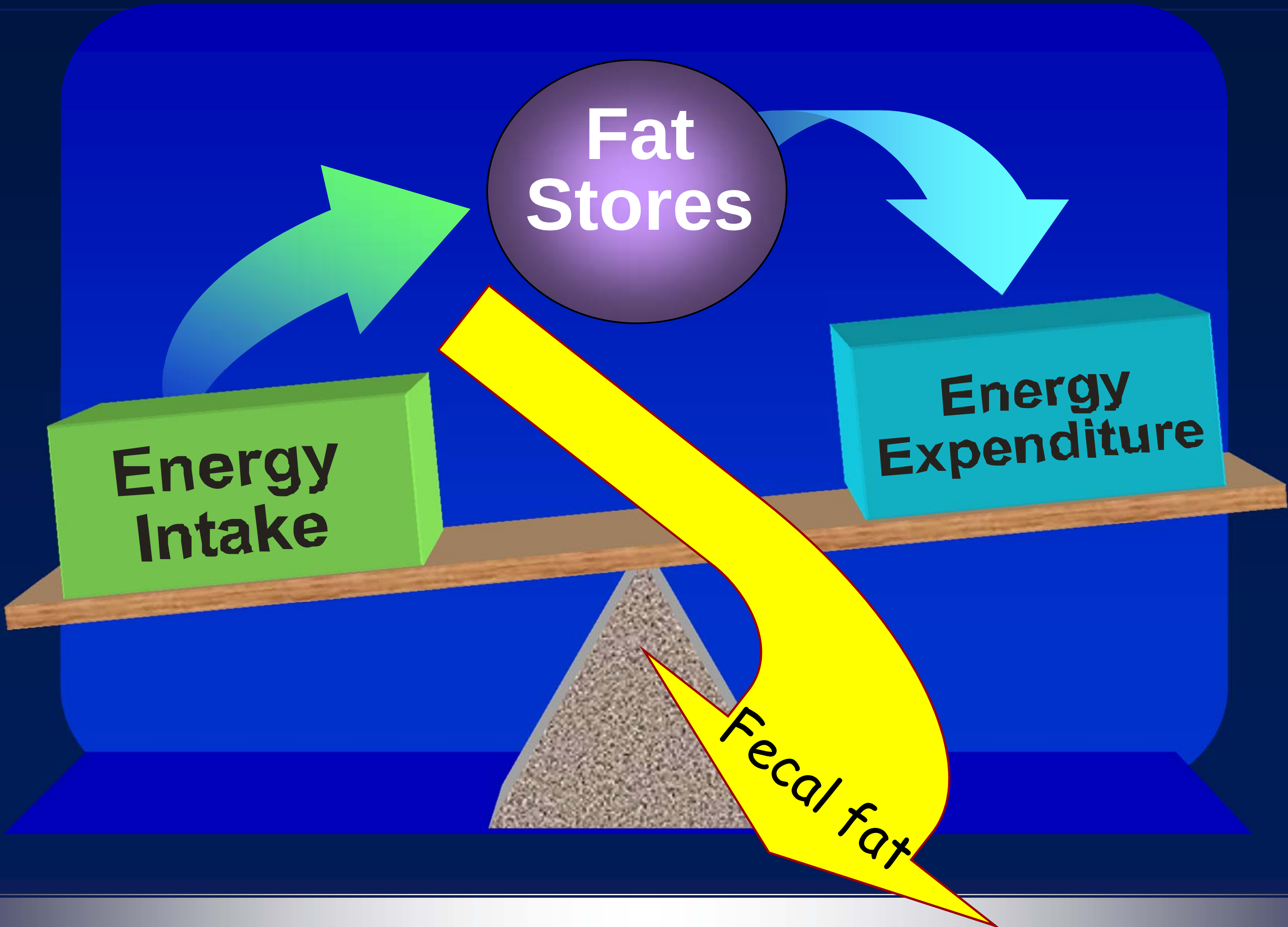
# Possible role of (dairy) protein

- Protein induces a higher degree of satiety per kcal than CHO or fat
- Protein is more thermogenic than CHO and fat
- Smaller decrease in FFM after weight loss in response to a high protein diet
- Several investigations indicate a role of protein in weight loss and weight maintenance (Baba 1999, Skov 1999, Mikkelsen 2000, Due 2004, Westerterp-Plantenga 2004)

# Obesity Is Caused by Long-Term Positive Energy Balance



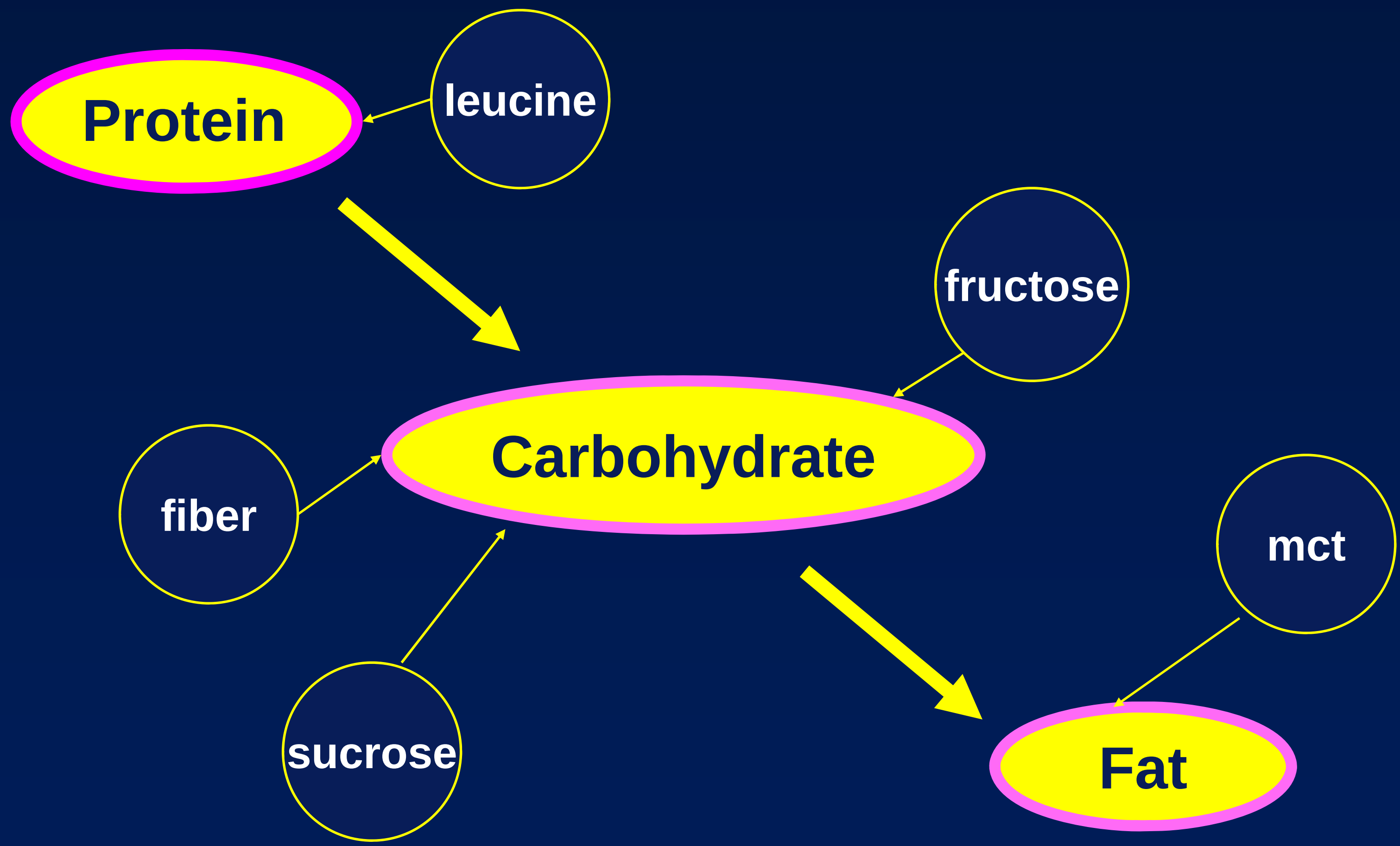
# Obesity Is Caused by Long-Term Positive Energy Balance



## Is protein the major component in dairy responsible for effect on energy balance ?

# Proposed Hierarchy of Satiety

**Need hypothesis-driven studies to determine differences**



# Can more protein improve weight loss ?



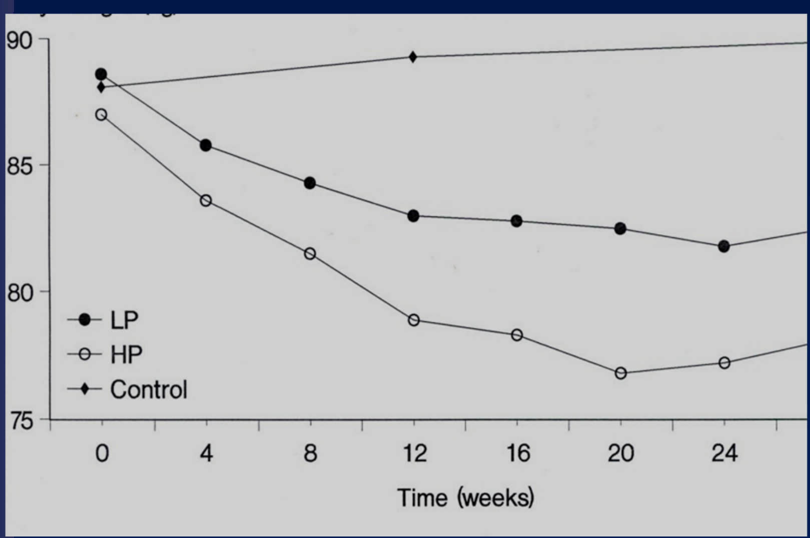


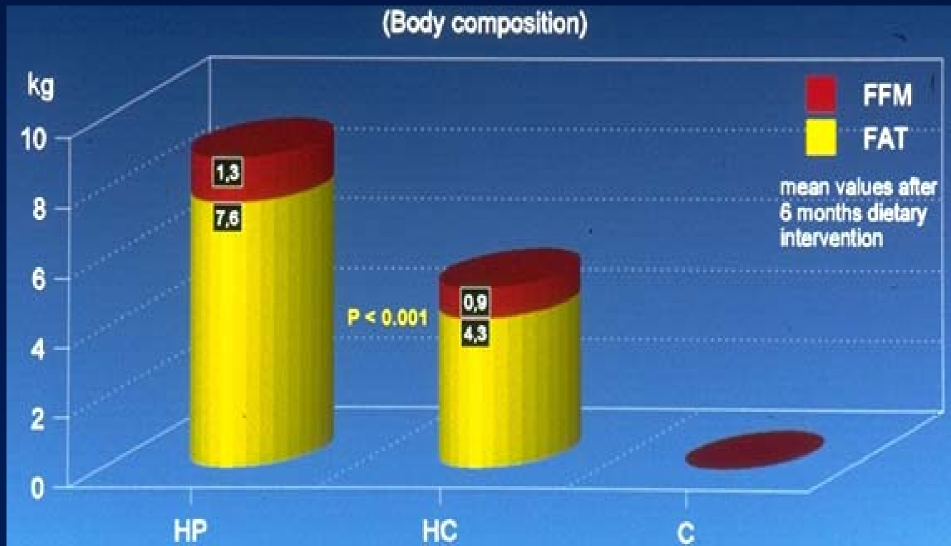
or



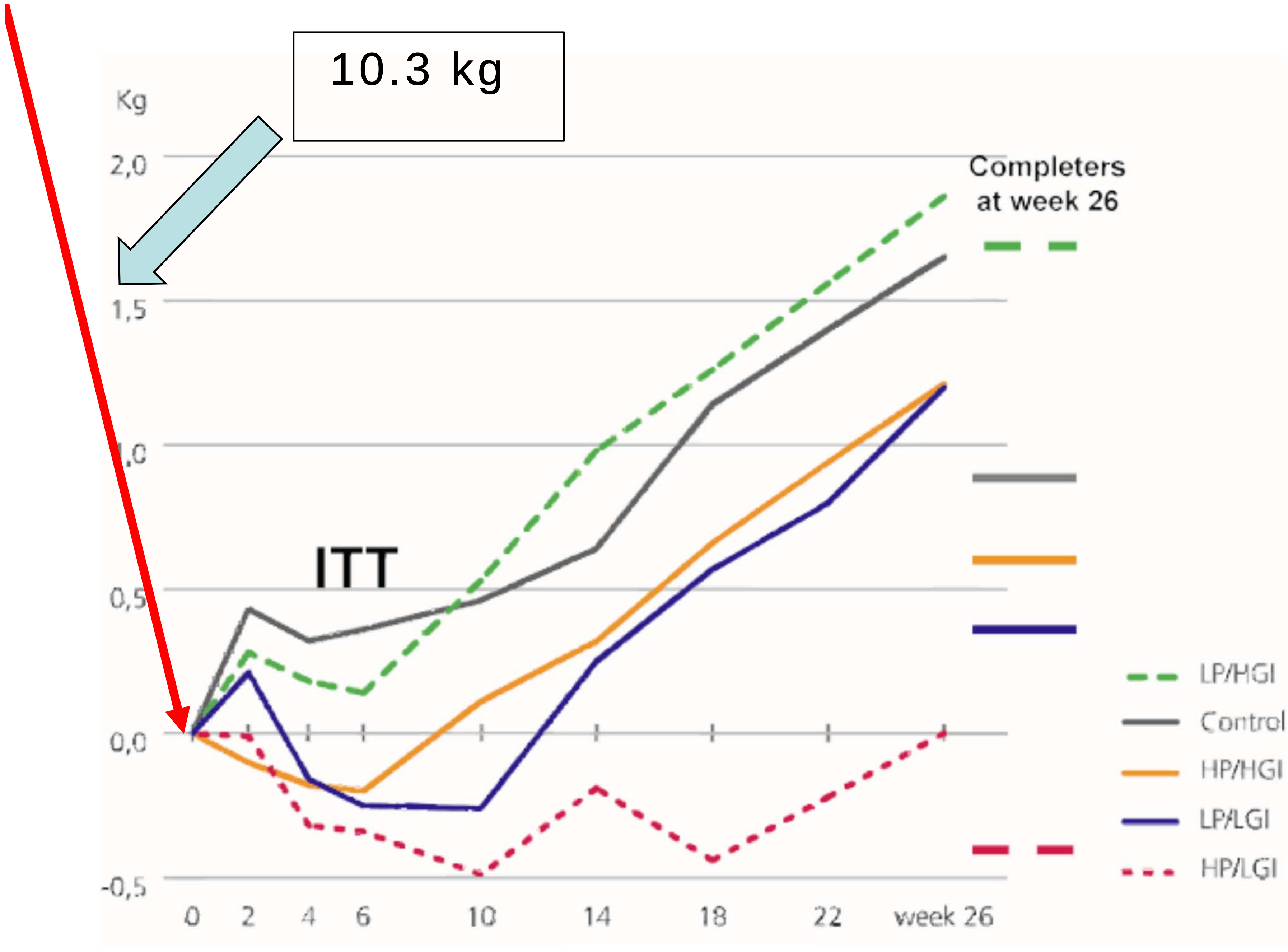
# A randomized 6 month trial on two fat-reduced diets: High CHO *versus* high protein

Weight loss and fat loss



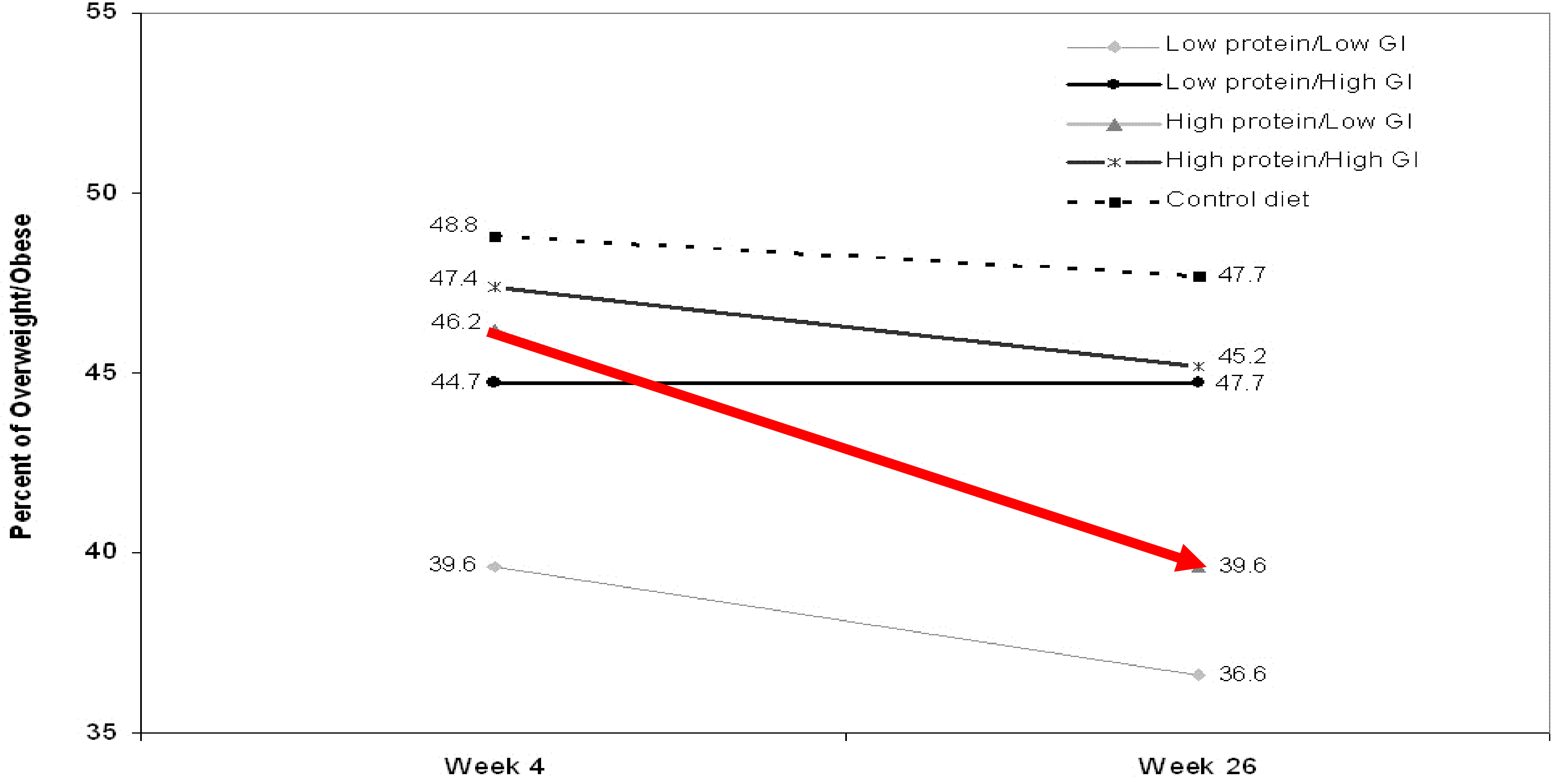




Skov et al. Int. J. Obes 1999;23:528-536




Larsen TM et al NEJM 2010

# Spontaneous change in prevalence of overweight/obesity in household children



# The role of milk (protein+calcium) on appetite, caloric intake and thermogenesis

*British Journal of Nutrition* (2007), **97**, 579–583
DOI: 10.1017/S0007114507339846


# Increased satiety after intake of a chocolate milk drink compared with a carbonated beverage, but no difference in subsequent *ad libitum* lunch intake

Angela Harper[1,2]*, Anita James[1], Anne Flint[1] and Arne Astrup[1]

**Table 1.** Energy and macronutrient composition of the preload beverages

| | Chocolate milk | Cola |
|---|---|---|
| Volume (ml) | 500* | 500 |
| Energy (kJ) | 900 | 900 |
| Carbohydrate (g) | 36 | 53 |
| Protein (g) | 12·6 | 0 |
| Fat (g) | 1·8 | 0 |
| Energy density (kJ/g) | 1·6 | 1·6 |

*Provided as 346 ml chocolate milk and 154 ml water in a separate glass.

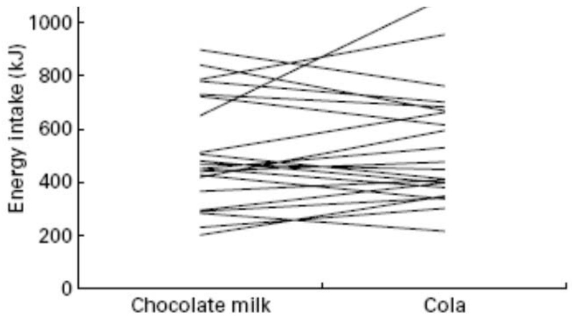
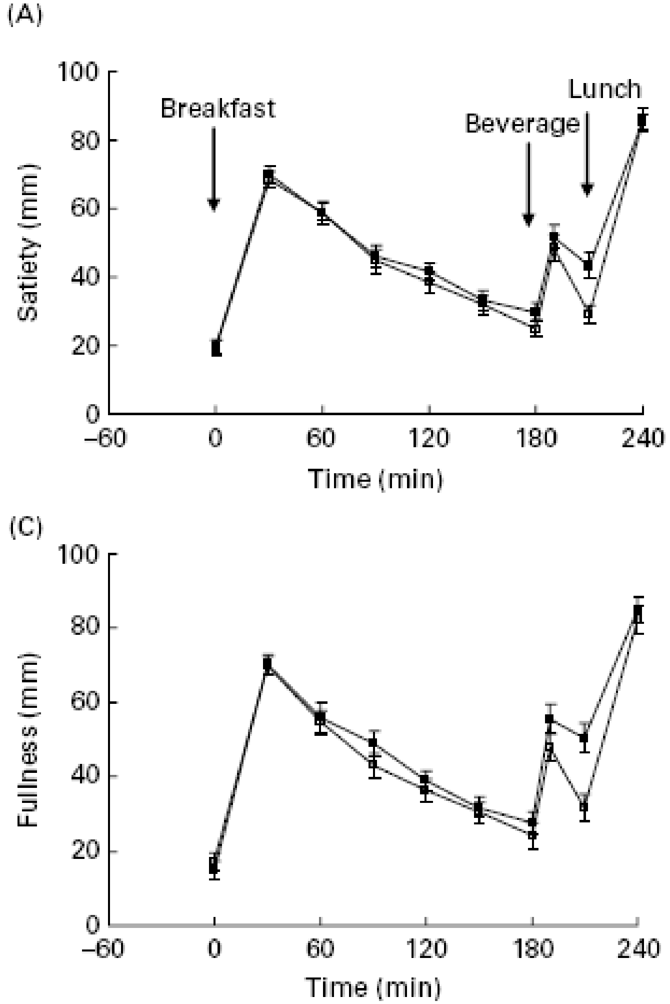



**Fig. 2.** Spontaneous energy intake at an *ad libitum* lunch 30 min after consumption of a preload beverage, chocolate milk or cola, in twenty-two normal-weight men. Mean energy intakes at lunch were 3145 (SD 1268) kJ after the chocolate milk and 3286 (SD 1346) kJ after cola. There was no significant difference in energy intake at lunch ($P=0.42$).



## Skim milk compared with a fruit drink acutely reduces appetite and energy intake in overweight men and women[1–3]

*Emma R Dove, Jonathan M Hodgson, Ian B Puddey, Lawrence J Beilin, Ya P Lee, and Trevor A Mori*

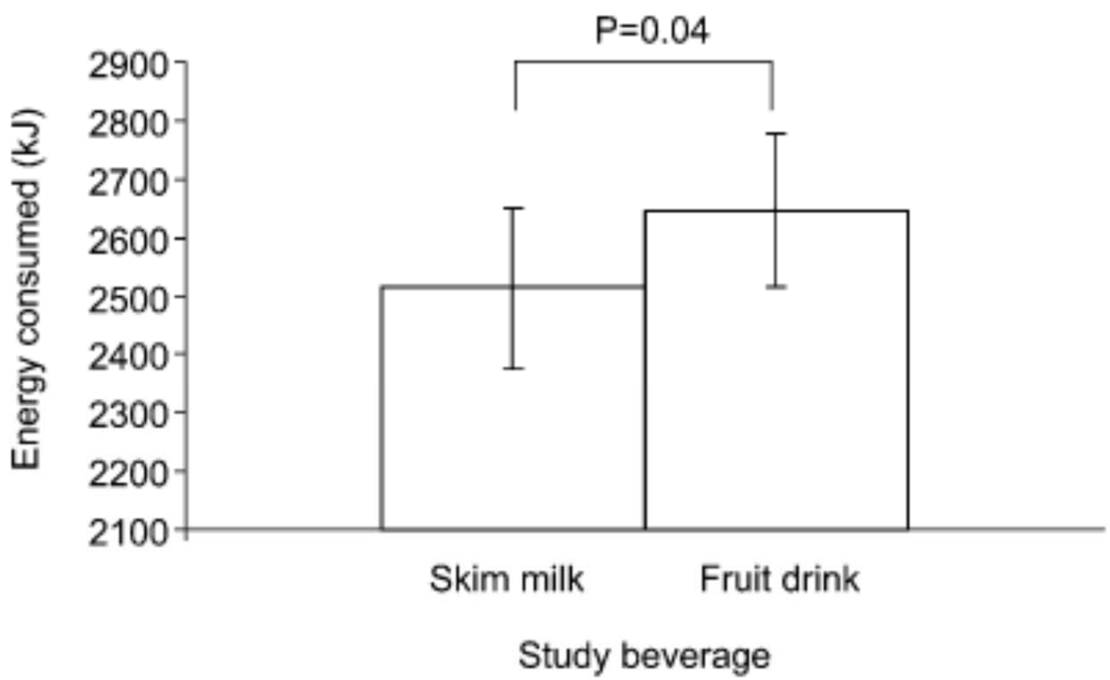



**FIGURE 2.** Mean (±SEM) energy intake at the lunch test meal for each study treatment.

Effects of protein or calcium ?

# Sucrose-sweetened beverages increase fat storage in the liver, muscle, and visceral fat depot: a 6-mo randomized intervention study[1–3]

*Maria Maersk, Anita Belza, Hans Stødkilde-Jørgensen, Steffen Ringgaard, Elizaveta Chabanova, Henrik Thomsen, Steen B Pedersen, Arne Astrup, and Bjørn Richelsen*

**ABSTRACT**

**Background:** The consumption of sucrose-sweetened soft drinks (SSSDs) has been associated with obesity, the metabolic syndrome,

regular cola (11, 12). On the other hand, artificially sweetened soft drinks have also been associated with obesity and the metabolic syndrome (5, 13). However, to our knowledge, no

[2] Supported by grants from The Danish Council for Strategic Research, The Food Study Group/Danish Ministry of Food, Agriculture and Fisheries, Novo Nordic Foundation, and Clinical Institute at Aarhus University, Denmark. The semiskim milk was donated by the Danish Dairy Company, Arla Foods, but without any influence on the design, interpretation, or conclusions of the study.

**Design:** Overweight subjects (*n* = 47) were randomly assigned to 4 different test drinks (1 L/d for 6 mo): SSSD (regular cola), isocaloric semiskim milk, aspartame-sweetened diet cola, and water. The amount of intrahepatic fat and intramyocellular fat was measured with $^1$H-magnetic resonance spectroscopy. Other endpoints were fat mass, fat distribution (dual-energy X-ray absorptiometry and magnetic resonance imaging), and metabolic risk factors.

**TABLE 1**

Composition and energy content of the 4 test drinks[1]

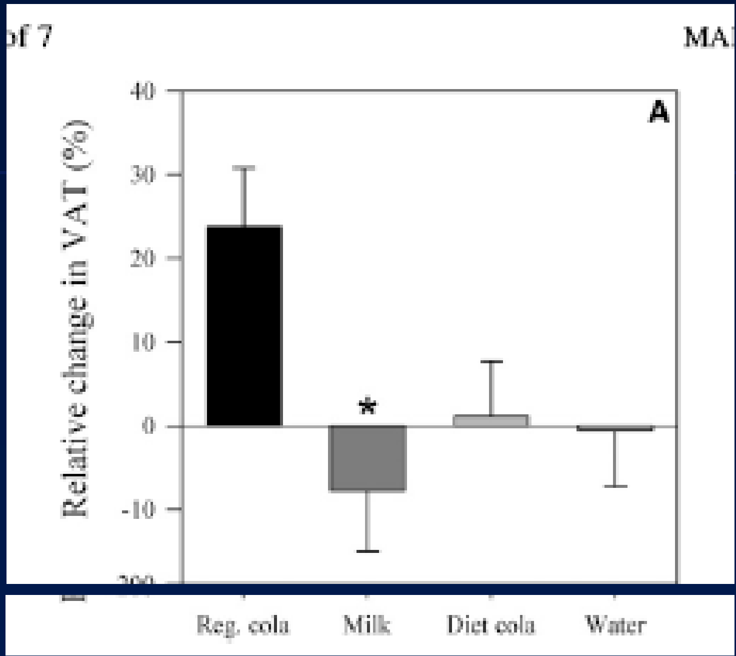
| | Sucrose-sweetened regular cola | Milk | Aspartame-sweetened diet cola | Water |
|---|---|---|---|---|
| Carbohydrate (g/100 mL) | 10.6 | 4.7 | 0 | 0 |
| Protein (g/100 mL) | 0 | 3.4 | <0.1 | 0 |
| Fat (g/100 mL) | 0 | 1.5 | 0 | 0 |
| Energy (kJ/d) | 1800 | 1900 | 15 | 0 |
| Volume (mL) | 1000 | 1000 | 1000 | 1000 |
| Energy density (kJ/g) | 1.8 | 1.9 | 0.015 | 0 |

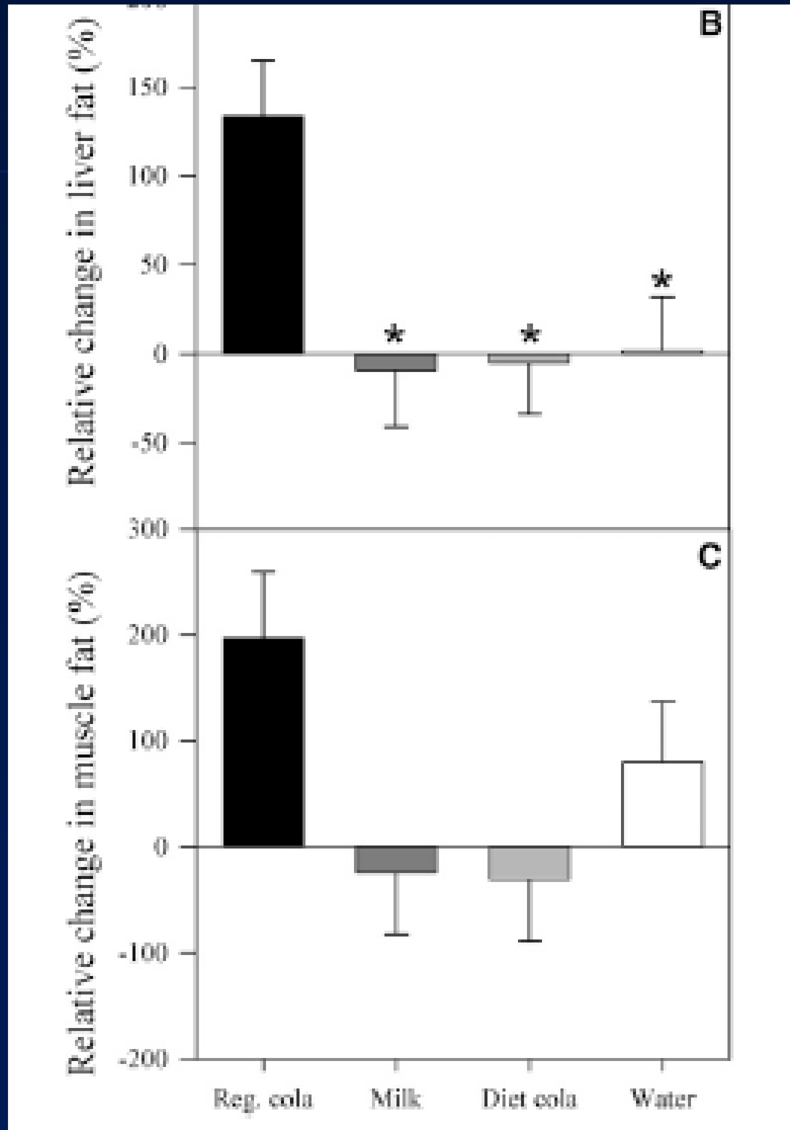
[1] The subjects drank 1 L of 1 of 4 test drinks daily for 6 mo.

**TABLE 3**

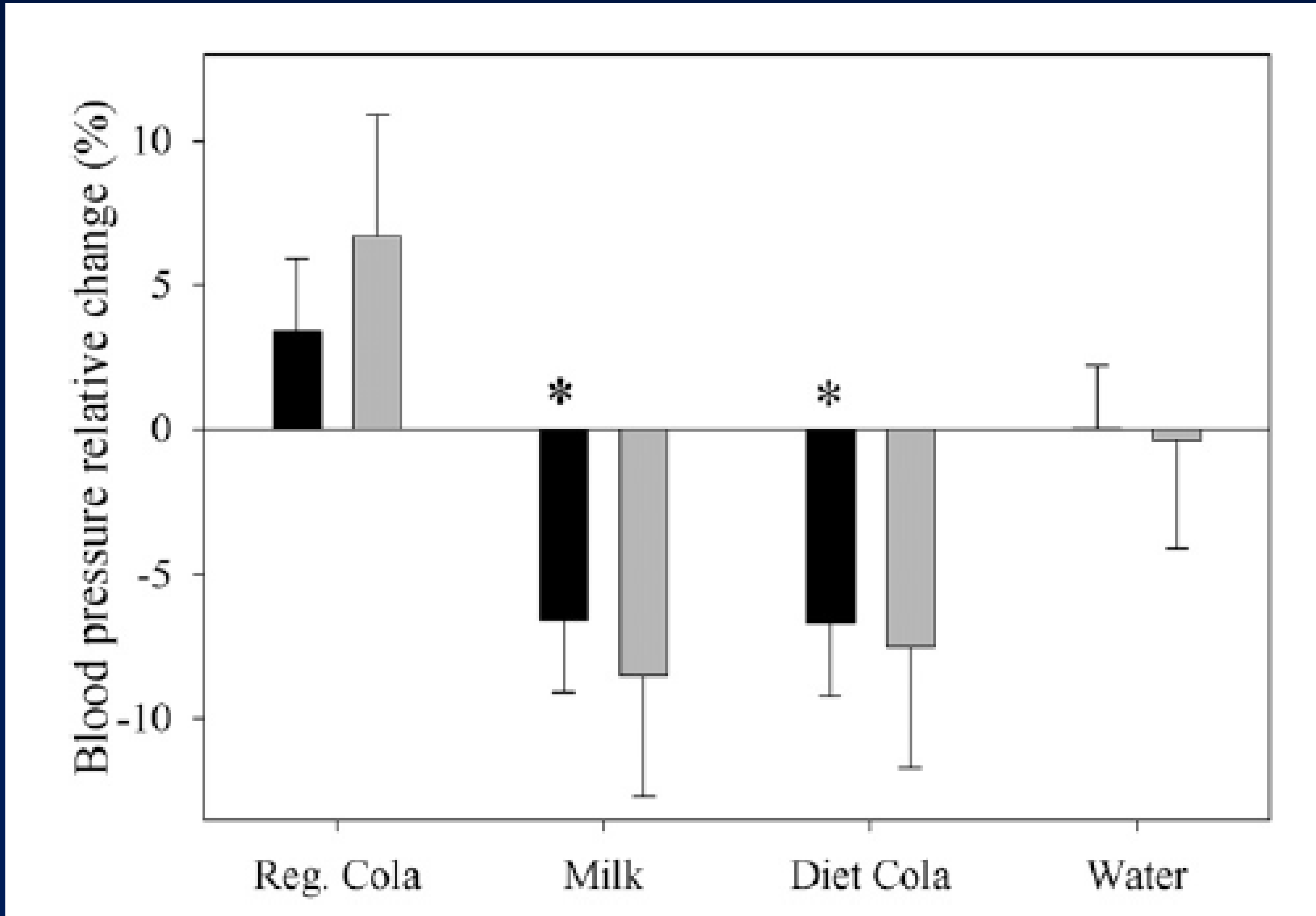
Changes from baseline to 6 mo in fatness, body composition, and metabolic risk factors[1]

| | Regular cola | Milk | Diet cola | Water | *P* value[2] |
|---|---|---|---|---|---|
| | % | % | % | % | |
| Body weight | 1.28 ± 1.1[3] | 1.36 ± 1.1 | 0.114 ± 1.1 | 0.576 ± 1.0 | 0.8 |
| Total fat mass | 3.14 ± 2.7 | 1.42 ± 2.5 | −0.52 ± 2.5 | 0.490 ± 2.6 | 0.8 |
| SAAT | 4.98 ± 2.8 | 3.10 ± 2.9 | −2.79 ± 2.7 | −4.30 ± 2.7 | 0.07 |
| VAT/SAAT | 18.1 ± 6.0 | −12.5 ± 6.1 | 4.59 ± 5.5 | 3.90 ± 5.7 | 0.013[a] |
| Lean mass | 0.423 ± 0.8 | 1.43 ± 0.8 | 0.951 ± 0.8 | −0.189 ± 0.8 | 0.5 |
| Bone mass | −1.39 ± 0.6 | 0.571 ± 0.6 | −0.926 ± 0.6 | −0.909 ± 0.6 | 0.1 |
| Leptin | 25.2 ± 9.7 | 9.11 ± 8.6 | −2.20 ± 8.6 | 3.72 ± 8.2 | 0.2 |
| Total cholesterol | 11.4 ± 3.2 | 0.634 ± 3.0 | −5.89 ± 3.0 | −0.159 ± 2.8 | 0.004[b] |
| Triglycerides | 32.7 ± 8.6 | −0.301 ± 8.1 | −14.1 ± 8.1 | −14.2 ± 7.7 | 0.001[c] |


A
Relative change in VAT (%)
40
30
20
10
0
-10
*
Reg. cola
Milk
Diet cola
Water


B
Relative change in liver fat (%)
150
100
50
0
-50
*
*
*
C
Relative change in muscle fat (%)
300
200
100
0
-100
-200
Reg. cola
Milk
Diet cola
Water

# Effects on Blood Pressure



# The role of calcium in body weight


Nyhedsquiz
I suspect she drinks milk

# Evidence from a randomised trial

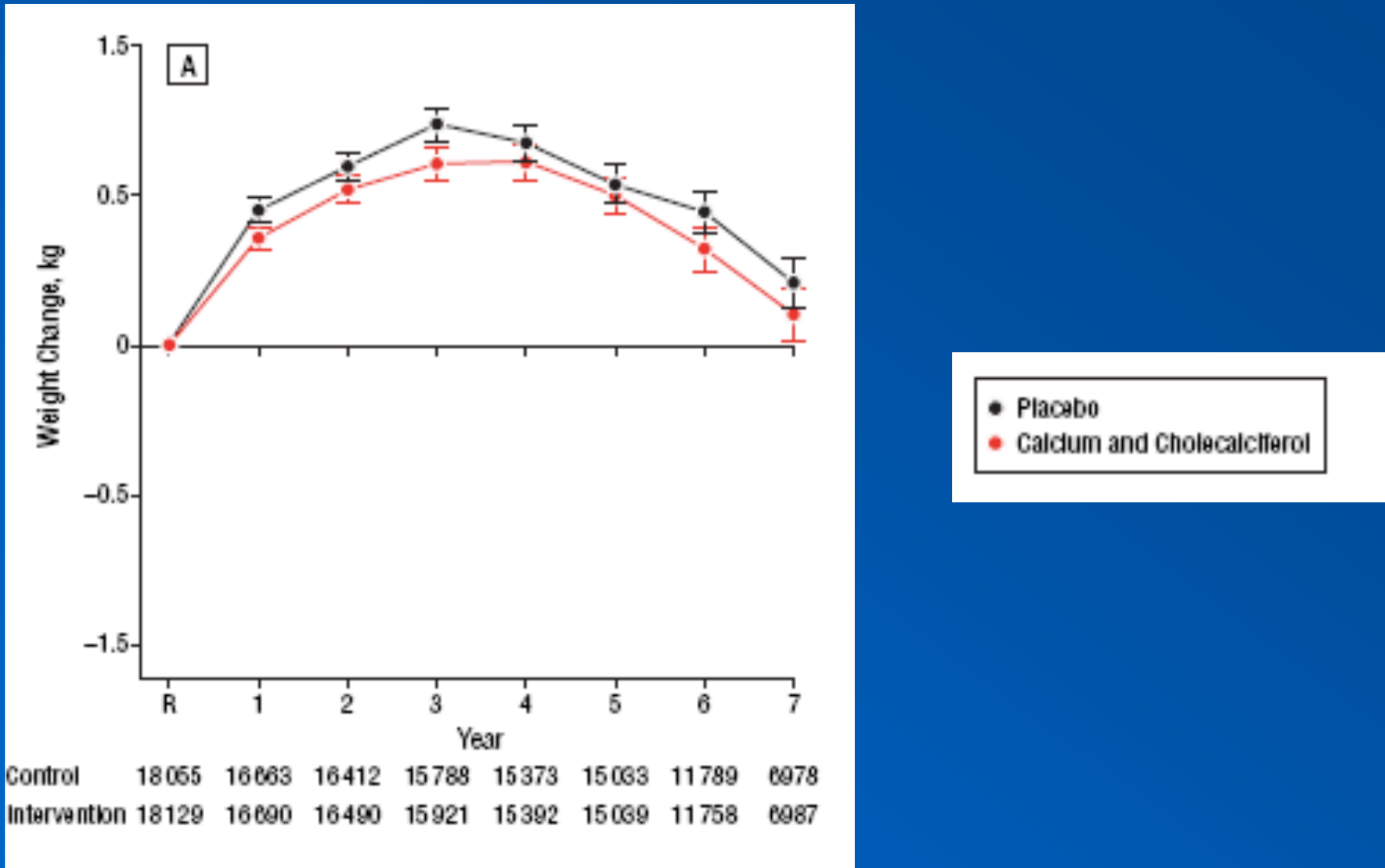
ORIGINAL INVESTIGATION

## Calcium Plus Vitamin D Supplementation and the Risk of Postmenopausal Weight Gain

*Bette Caan, DrPH; Marian Neuhouser, PhD; Aaron Aragaki, MS; Cora Beth Lewis, MD; Rebecca Jackson, MD; Meryl S. LeBoff, MD; Karen L. Margolis, MD; Lynda Powell, PhD; Gabriel Uwaifo, MD; Evelyn Whitlock, MD; Judy Wylie-Rosett, EdD; Andrea LaCroix, PhD*

**Methods:** A randomized, double-blinded, placebo-controlled trial was performed with 36 282 postmenopausal women, aged 50 to 79 years, who were already enrolled in the dietary modification and/or hormone therapy arms of the Women's Health Initiative clinical trial. Women were randomized at their first or second annual visit to receive a dose of 1000 mg of elemental calcium plus 400 IU of cholecalciferol (vitamin D) or placebo daily. Change in body weight was ascertained annually for an average of 7 years.

*Arch Intern Med. 2007;167:893-902*




Women with a low daily calcium intake (<1200mg) at baseline who were randomized to supplements were:

- 11% less likely to experience small weight gains (1-3 kg)
- 11% less likely to gain more moderate amounts of weight (>3kg)

# Reduced digestibility of fat

See Accompanying Commentary by Zemel on pages 375–376

## High Dietary Calcium Reduces Body Fat Content, Digestibility of Fat, and Serum Vitamin D in Rats

*Emilia Papakonstantinou,* William P. Flatt,* Peter J. Huth,† and Ruth B.S. Harris**

**Abstract**

PAPAKONSTANTINOU, EMILIA, WILLIAM P. FLATT, PETER J. HUTH, AND RUTH B.S. HARRIS. High dietary calcium reduces body fat content, digestibility of fat, and serum vitamin D in rats. *Obes Res.* 2003;11:387–394.

*Objective:* This study investigated which aspect of energy balance was responsible for the decrease in body fat content of rats fed a high-calcium, high–dairy protein diet.

*Research Methods and Procedures:* Male Wistar rats were fed a control diet (25% kcal fat, 14% kcal protein from

**Key words:** digestible energy, fecal fat, vitamin D

### Introduction

Efficiency of energy utilization can be influenced by the macronutrient content of the diet. Thus, diet composition has the potential to determine the amount of energy stored as body fat for any given level of energy intake. It is well established that energy consumed as fat is stored more efficiently than

# Reduced digestibility of fat

**Table 3.** Fecal analysis

| | Control | High-calcium | Statistical significance |
|---|---|---|---|
| Fecal weight (g/5 days) | 8.9 ± 0.6 | 15.9 ± 0.6 | $p < 0.01$ |
| Fecal fat (%) | 0.11 ± 0.01 | 0.13 ± 0.02 | |
| Fecal fat (g/5 days) | 0.95 ± 0.11 | 2.04 ± 0.25 | $p < 0.001$ |
| Fecal ash (%) | 0.12 ± 0.001 | 0.37 ± 0.005 | $p < 0.001$ |
| Fecal ash (g/5 days) | 1.1 ± 0.1 | 5.8 ± 0.2 | $p < 0.001$ |

# Study I

International Journal of Obesity (2005), 1–10

0307-0565/05 $30.00
www.nature.com/ijo

## PAPER

# Effect of short-term high dietary calcium intake on 24-h energy expenditure, fat oxidation, and fecal fat excretion

R Jacobsen[1], JK Lorenzen[1], S Toubro[1], I Krog-Mikkelsen[1] and A Astrup[1]*

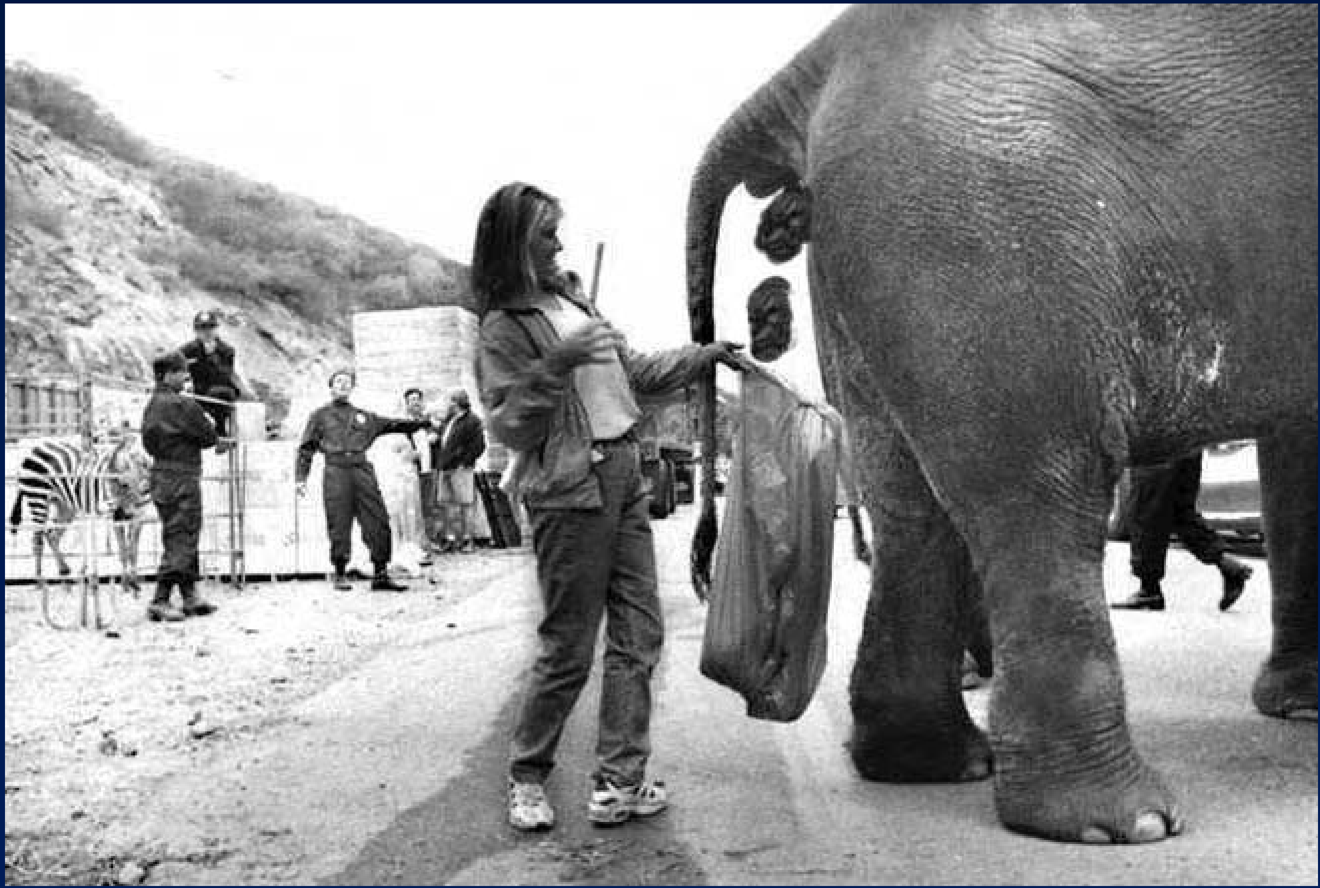
[1]*Department of Human Nutrition, Centre for Advanced Food Studies, The Royal Veterinary and Agricultural University, DK-1958 Frederiksberg C, Denmark*

**BACKGROUND:** Observational studies have shown an inverse association between dietary calcium intake and body weight, and a causal relation is likely. However, the underlying mechanisms are not understood.
**OBJECTIVE:** We examined whether high and low calcium intakes from mainly low-fat dairy products, in diets high or normal in protein content, have effects on 24-h energy expenditure (EE) and substrate oxidation, fecal energy and fat excretion, and concentrations of substrates and hormones involved in energy metabolism and appetite.
**DESIGN:** In all, 10 subjects participated in a randomized crossover study of three isocaloric 1-week diets with: low calcium and normal protein (LC/NP: 500 mg calcium, 15% of energy (E%) from protein), high calcium and normal protein (HC/NP: 1800 mg calcium, 15E% protein), and high calcium and high protein (HC/HP: 1800 mg calcium, 23E% protein)

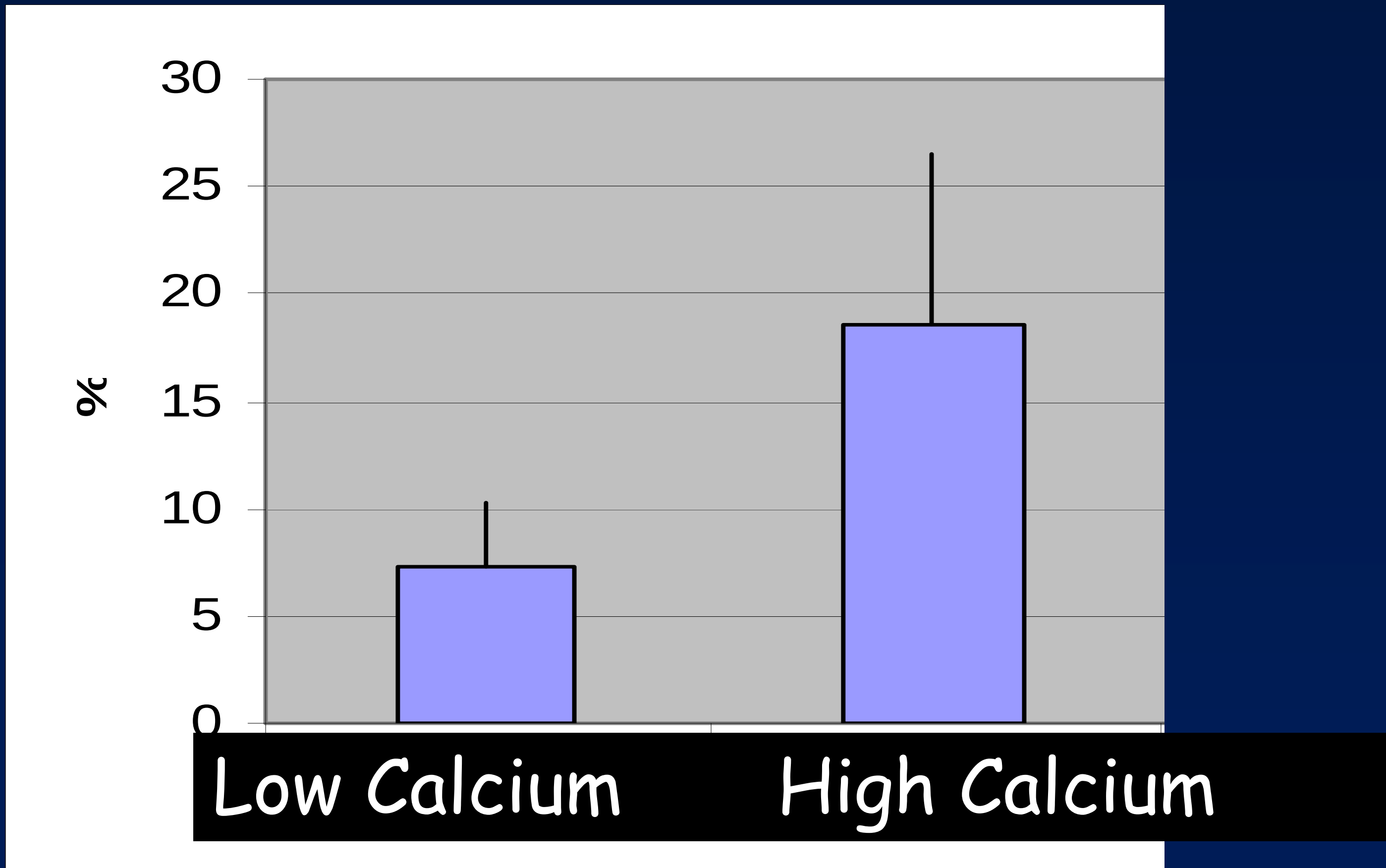
International Journal of Obesity (2005), 1–10
© 2005 Nature Publishing Group All rights reserved
www.nature.com/ijo

- **Measurement of energy expenditure: Respiration chamber**

# Methods: Fecal fat collection

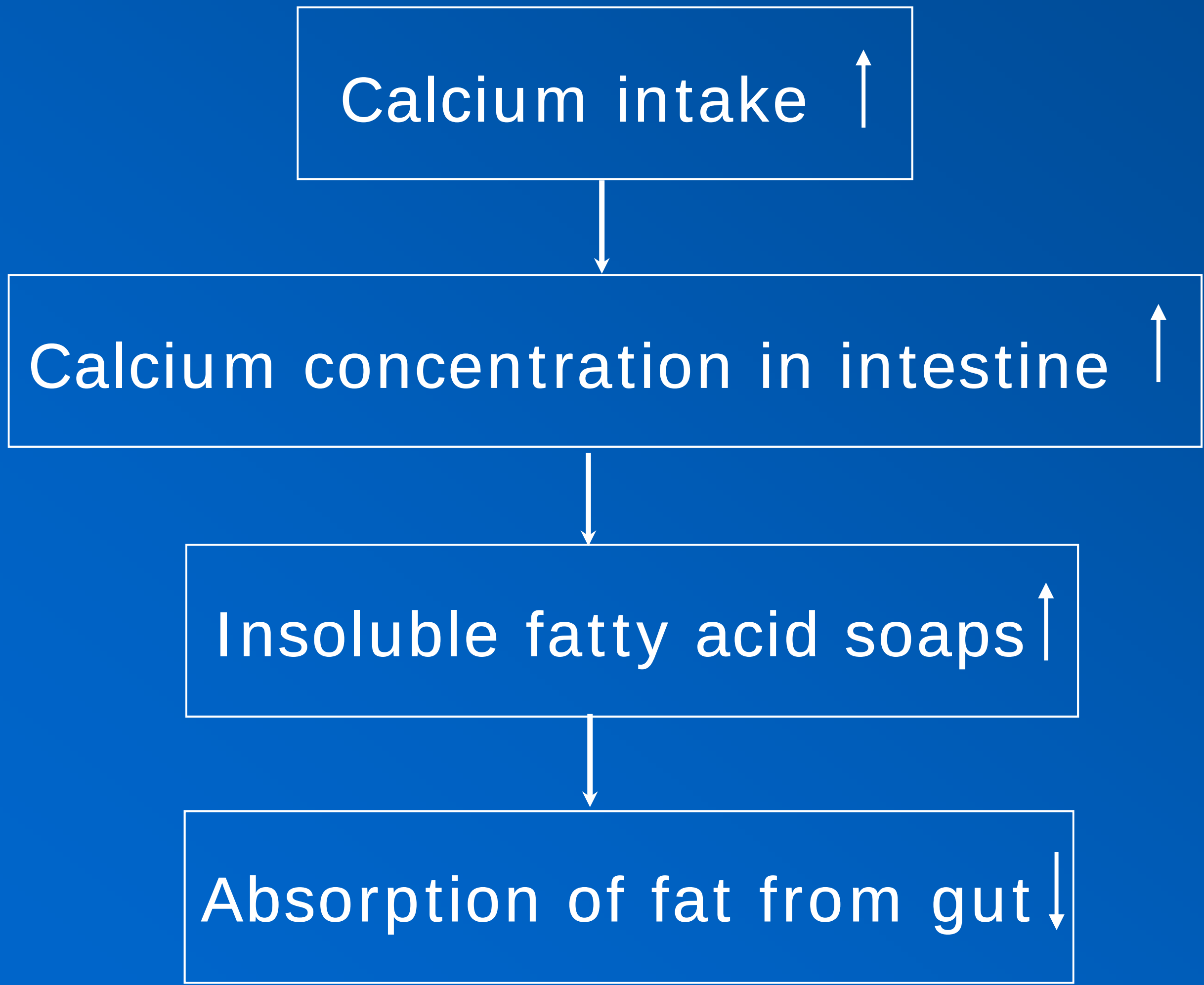


# Excretion of fat (% of intake)




Jacobsen R, Astrup A. Int. J.Obes (2005)

# Possible role of calcium: fat absorption



# Fat absorption

- Increased dairy calcium intake is associatedwith increased faecal fat excretion.
- This has been found in both animal and human studies.
- **Hypothesis: Impaired fat absorption might be seen as a diminished postprandial triglycerid response in humans**

Lorenzen JK, Astrup A. Am. J. Clin. Nutr. (2007)

# Does dairy calcium reduce postprandial lipidemia ?

Diet 1 (LC): calcium: 20 mg/MJ, dairy protein

Diet 2 (MC): calcium: 110mg/MJ, dairy protein

Diet 3 (HC): calcium: 200mg/MJ, dairy protein

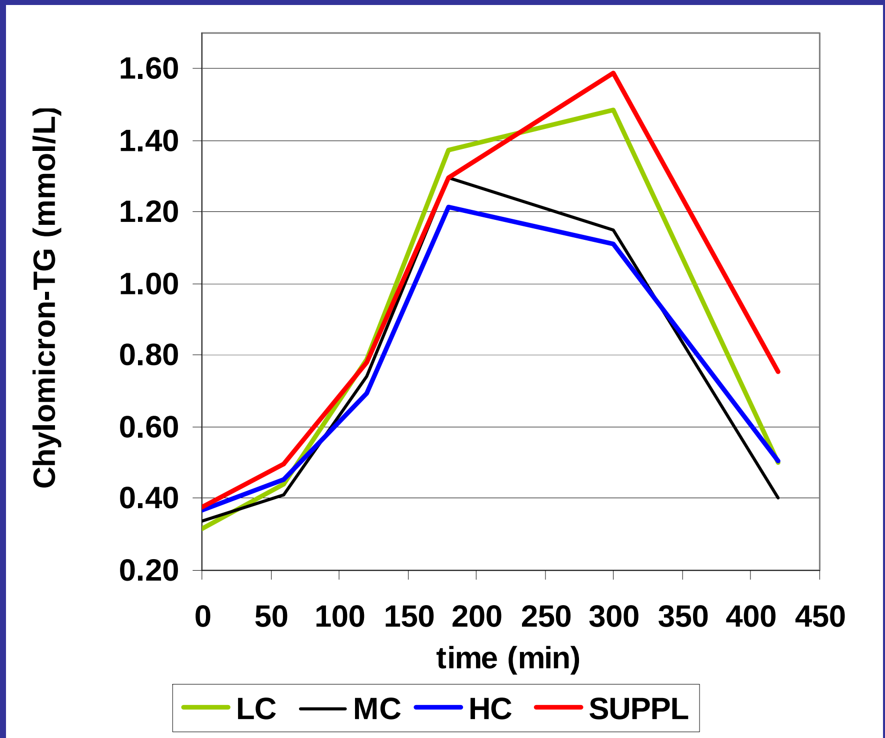
Diet 4 (Supp): calcium: 200mg/MJ (supplement), dairy protein

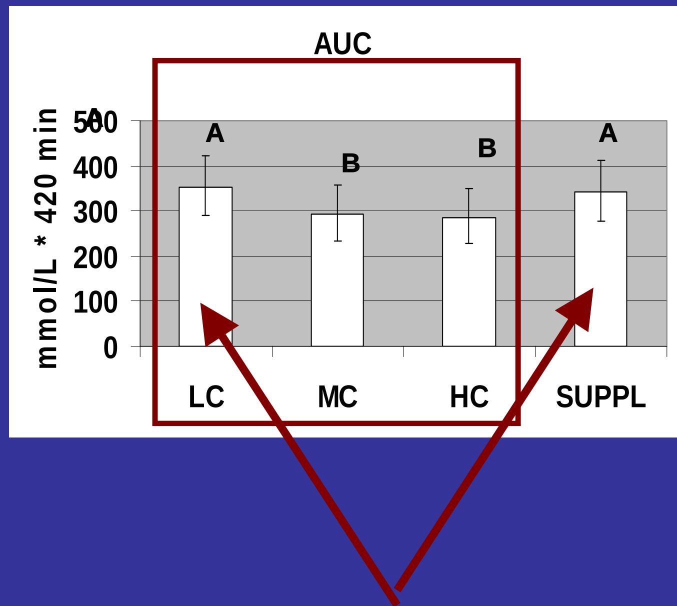
| | |
|---|---|
| Fat: | 39E% |
| Protein: | 15E% |
| Charbohydrate: | 46E% |

Lorenzen JK, Astrup A. Am. J. Clin. Nutr. (2007)

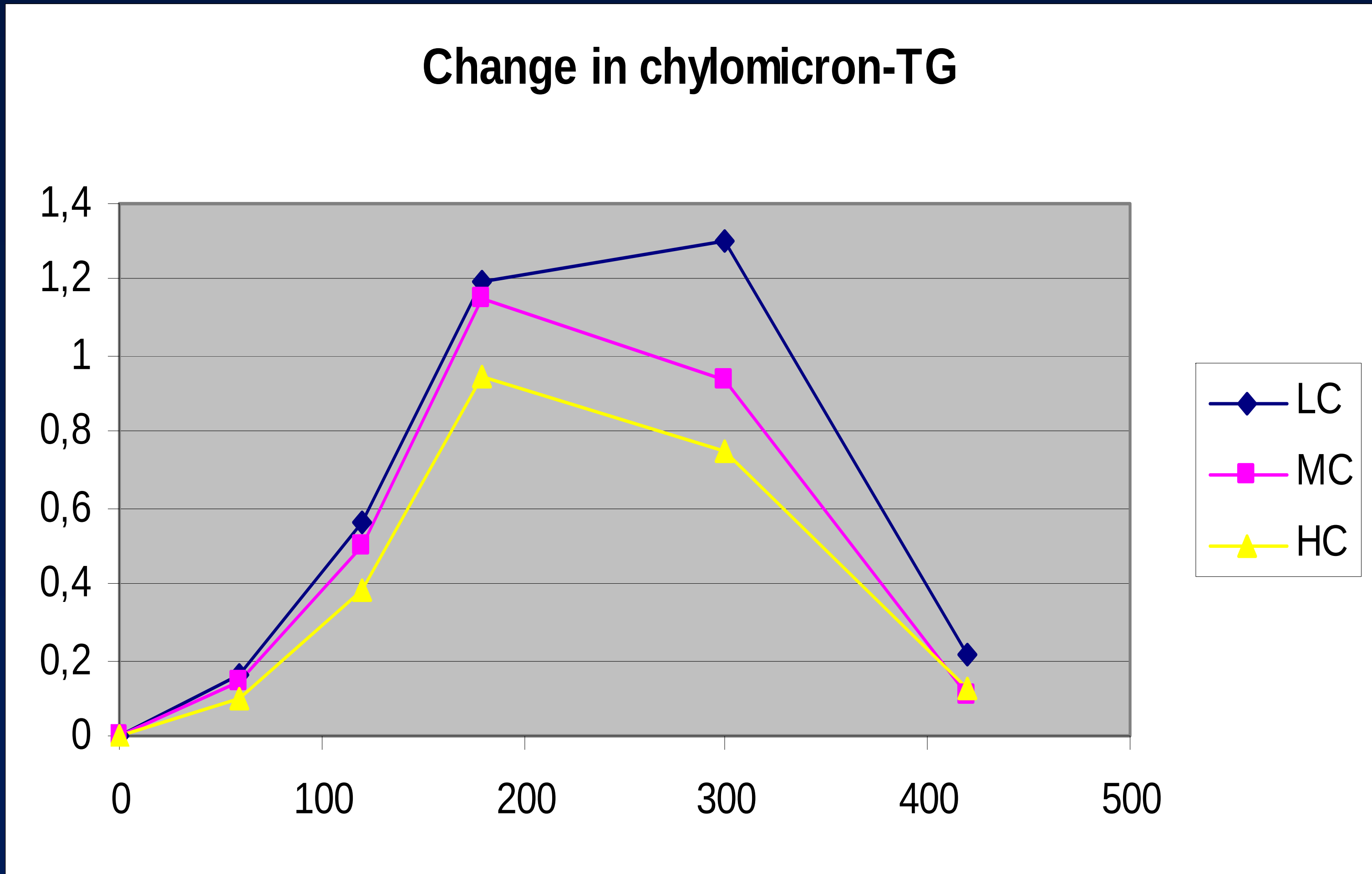

Lorenzen JK, Astrup A. Am. J. Clin. Nutr. (2007)

# Chylomicron triglycerides



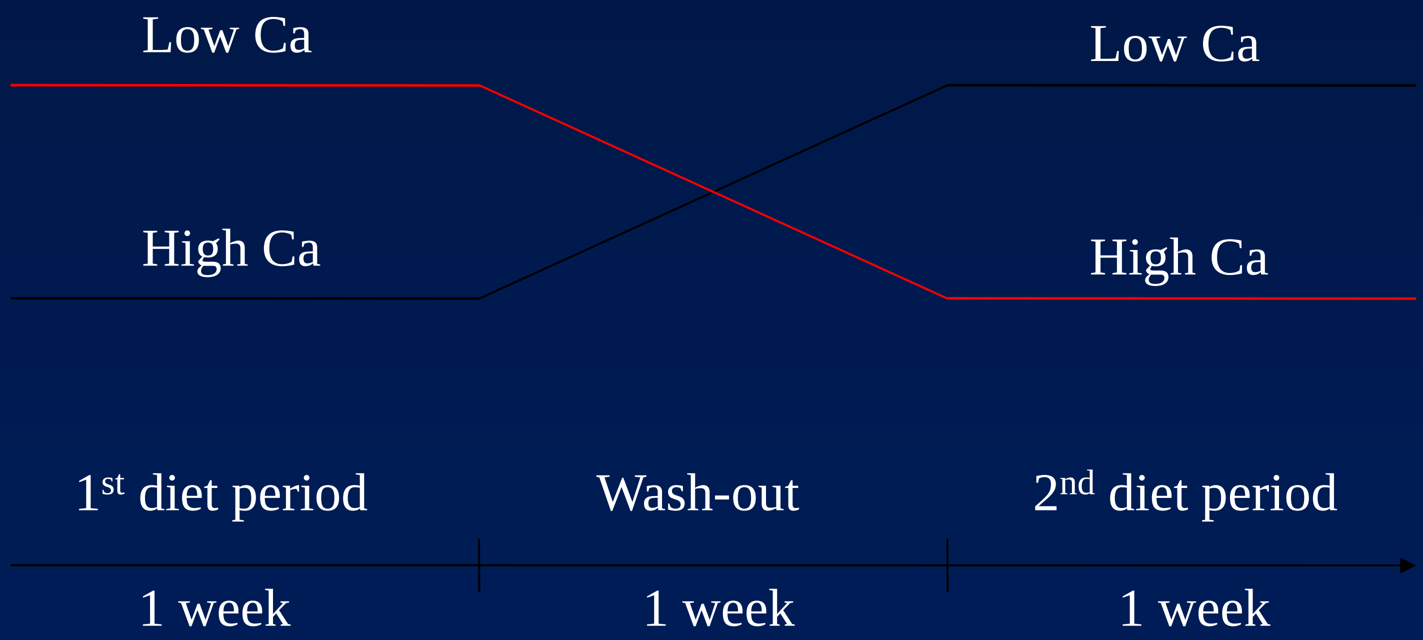
# Dairy Calcium reduces fat absorption




Lorenzen JK, Astrup A. Am. J. Clin. Nutr. (2007)

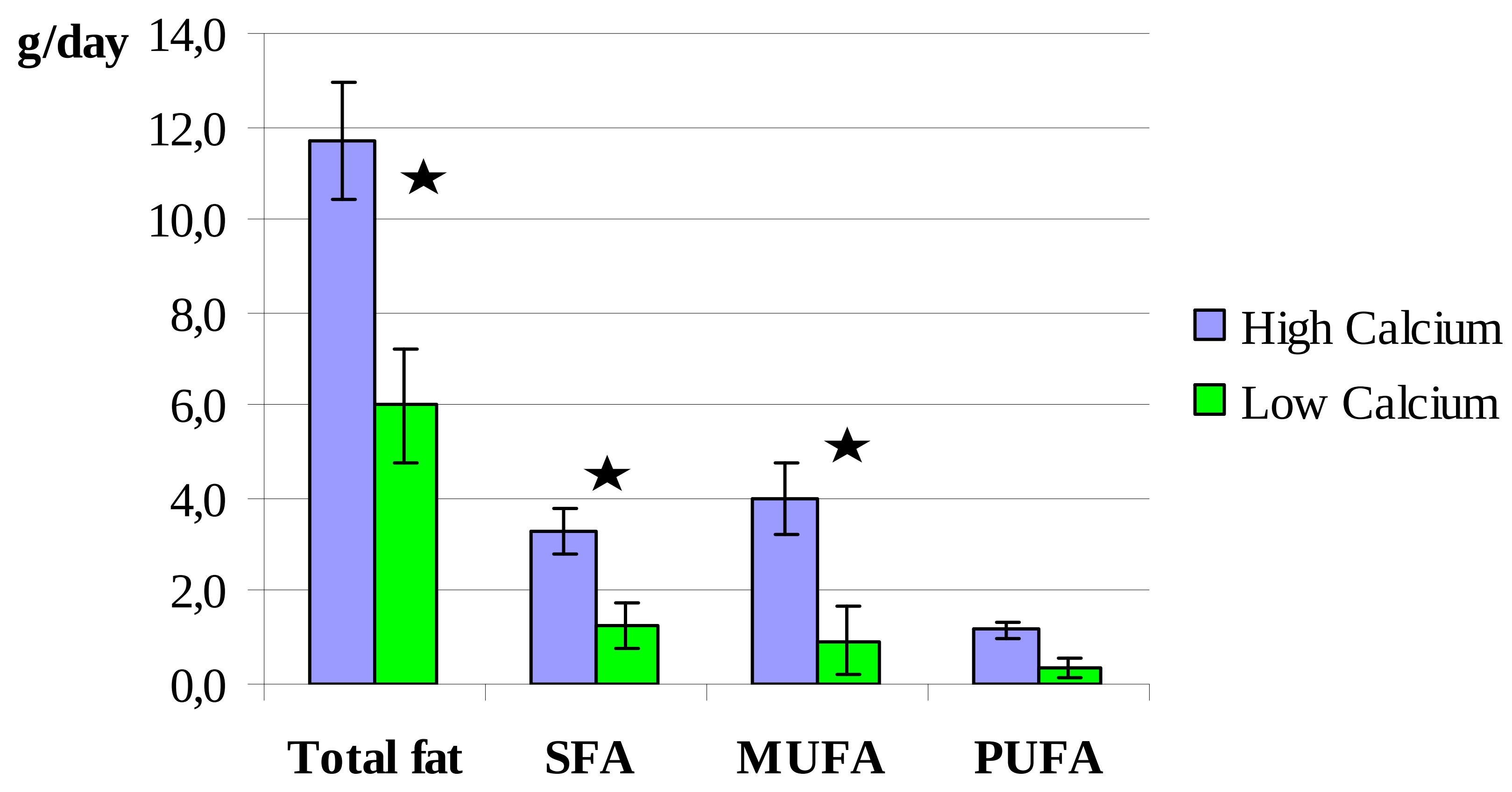
# Effect of calcium from low-fat dairy beverages on faecal fat excretion in moderately overweight women and men – a cross-over study

Sponsored by BBC, UK




Bendsen et al Int J Obes 2008;32:1816-24.

# Effect of Ca from low-fat dairy products on feacal fat excretion (LSmean values[1]), n=10




[1]Adjusted for total fat intake, SFA intake, MUFA intake and PUFA intake respectively

# BBC study

- Thus 20% more **energy** is excreted in feces on the high calcium diet than on the low calcium diet.
- Twice as much **fat** is excreted in feces on the high calcium diet compared to the low calcium diet.
- The difference in fat excretion (~6g/day) on the high (2000 mg/day) *versus* low (500 mg/day) calcium diet corresponds to a weight loss of approximately 2.5 kg over one year.
- An increase in calcium intake of 1500 mg/day, corresponding to the difference between the two diet types in calcium content, can be obtained by substituting 500 kcal of the habitual diet with a combination of certain low fat dairy products.

Bendsen et al Int J Obes 2008;32:1816-24.

# Study IV

Other Review

## Effect of calcium from dairy and dietary supplements on faecal fat excretion: a meta-analysis of randomized controlled trials

**obesity** reviews (2009) **10**, 475–486

R. Christensen[1], J. K. Lorenzen[2], C. R. Svith[1,2], E. M. Bartels[1,3], E. L. Melanson[4], W. H. Saris[5], A. Tremblay[6] and A. Astrup[2]

Aim:

to examine the effect of calcium from dairy products or supplements on faecal fat excretion.

# Design

All randomised and quasi-randomised controlled studies were considered eligible if they:

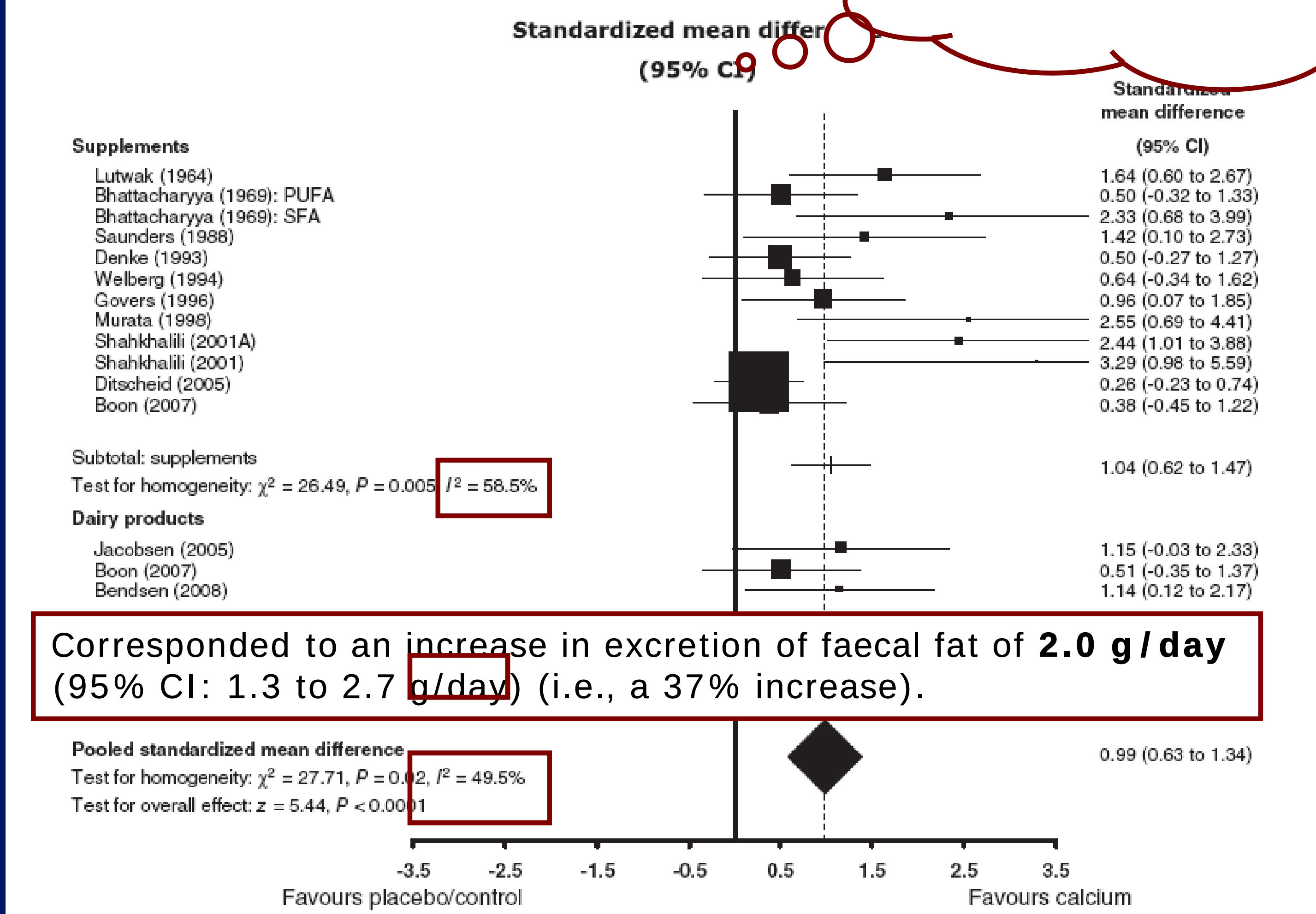
-enrolled healthy subjects, whether adult, adolescent or children more than 6 years of age

-examined the effect of intake of calcium from dairy products or dietary supplements

-reported changes in faecal fat – either as total fat or as fatty acids.

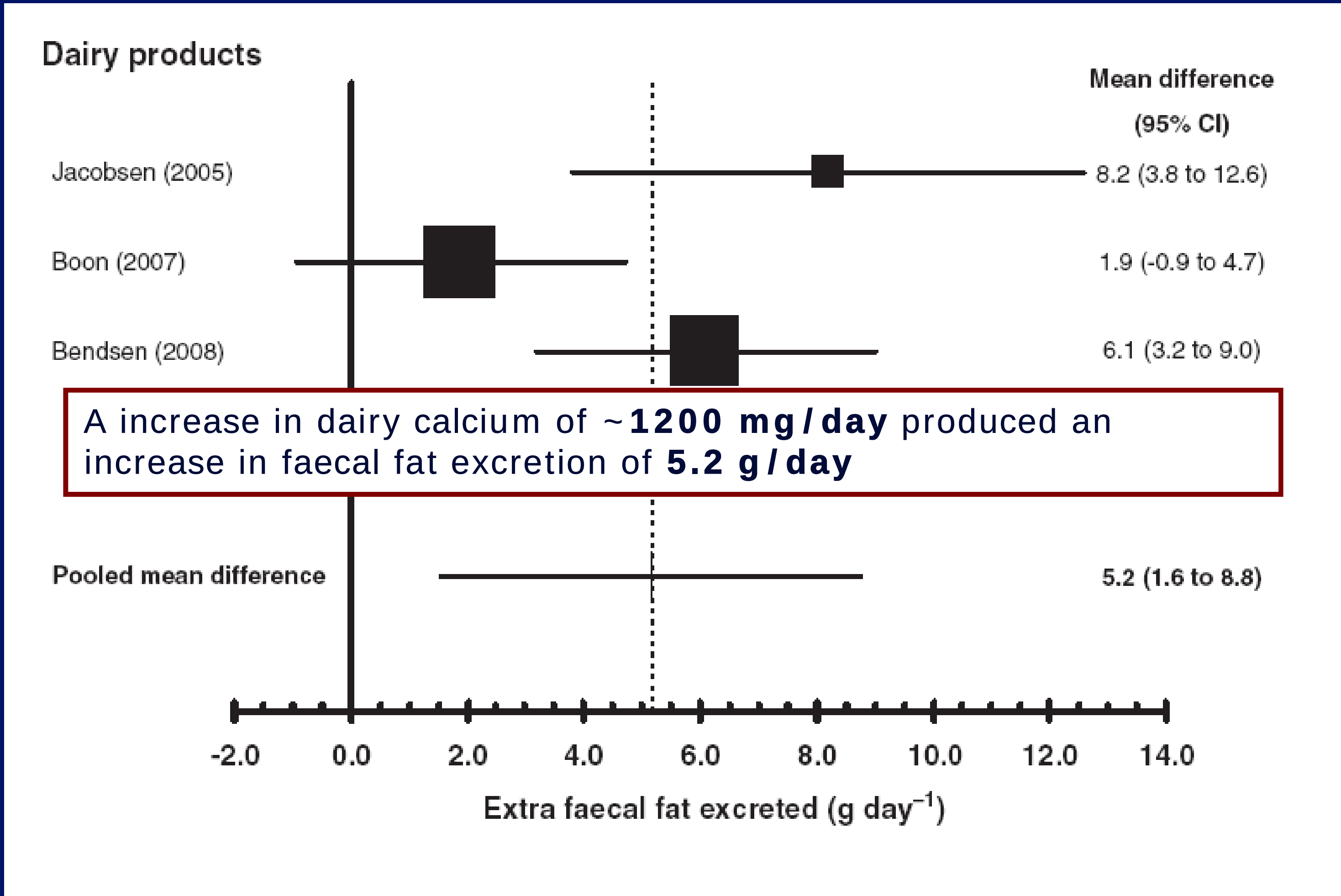
13 studies were deemed eligible. Two of these studies could be handled as having a factorial design, resulting in a final total of **15 sub-studies** included in the meta-analyses.

$$\text{SMD} = \frac{\text{Difference in mean outcome between groups}}{\text{Standard deviation of outcome among participants}}$$




Corresponded to an increase in excretion of faecal fat of **2.0 g/day** (95% CI: 1.3 to 2.7 g/day) (i.e., a 37% increase).

**Figure 2** Effects of calcium supplementation on faecal fat excretion; presented as supplements or dairy products. Every square represents the individual study's SMD with 95% CI indicated by horizontal lines; square sizes are directly proportional to the precision of the estimate.




A increase in dairy calcium of ~**1200 mg/day** produced an increase in faecal fat excretion of **5.2 g/day**

International Journal of Obesity (2012) 1 - 9

www.nature.com/ijo

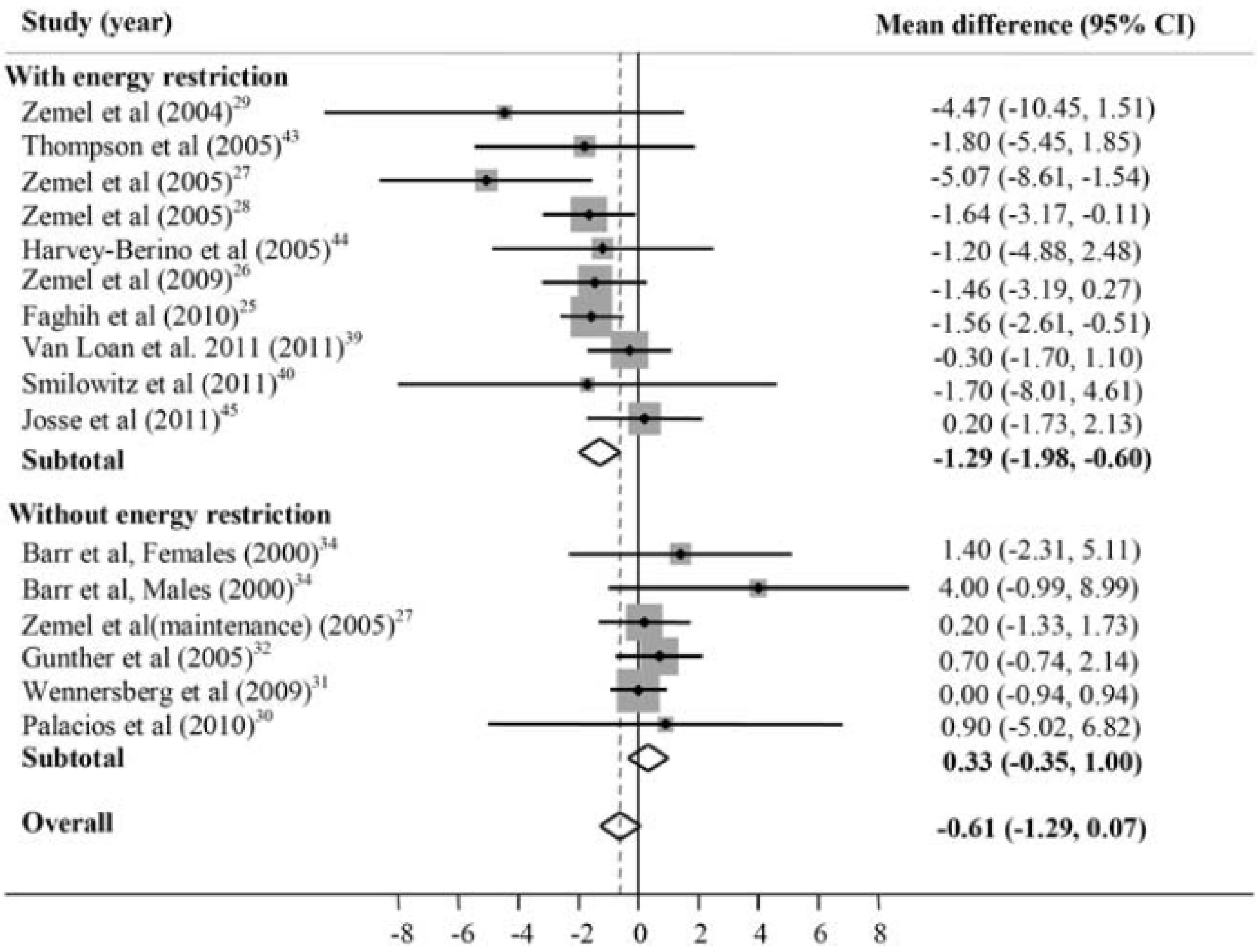
**ORIGINAL ARTICLE**

# Effect of dairy consumption on weight and body composition in adults: a systematic review and meta-analysis of randomized controlled clinical trials

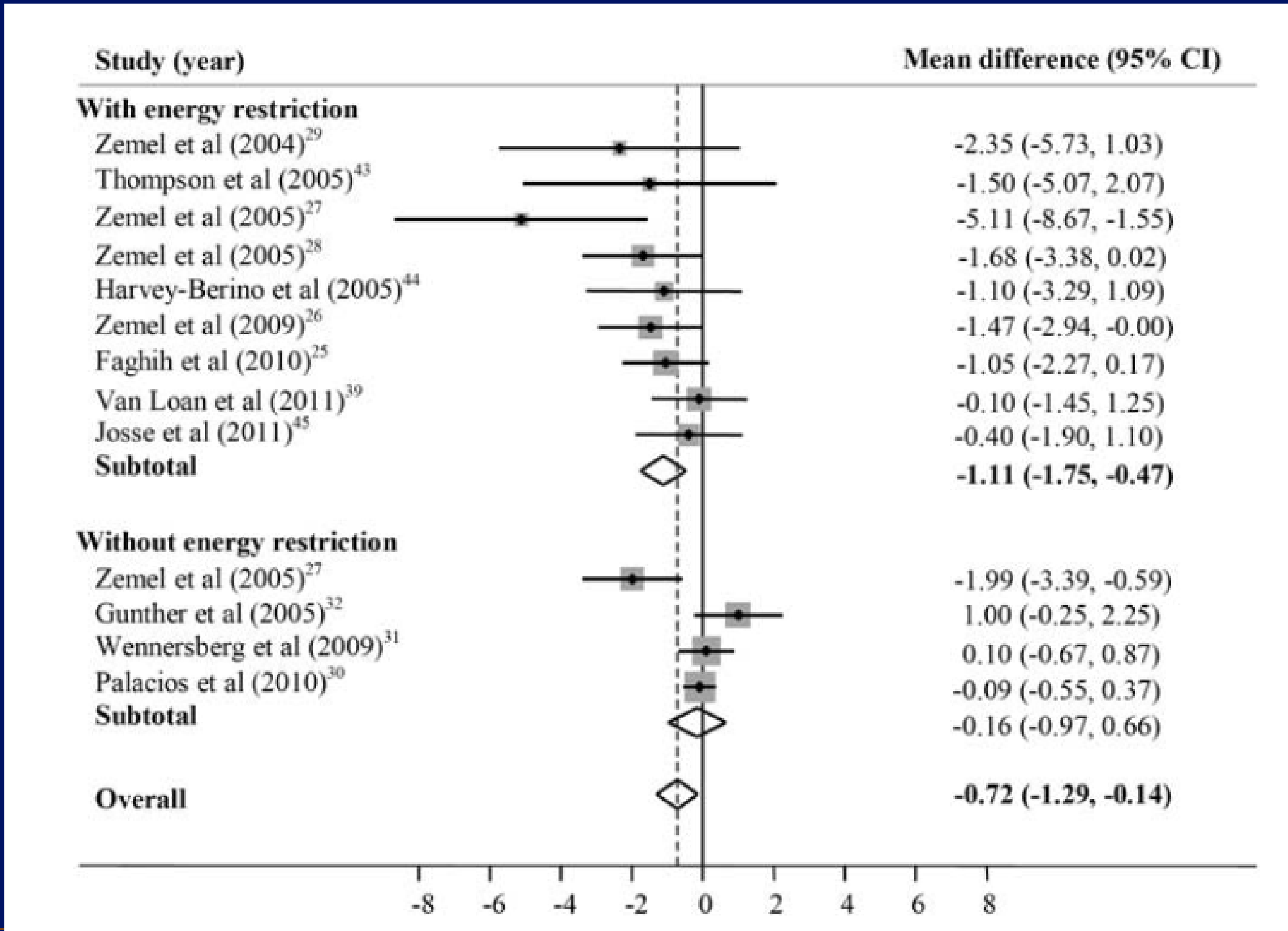
AS Abargouei[1,2], M Janghorbani[3], M Salehi-Marzijarani[3] and A Esmaillzadeh[1,2]

# Effect of high vs low dairy on weight loss

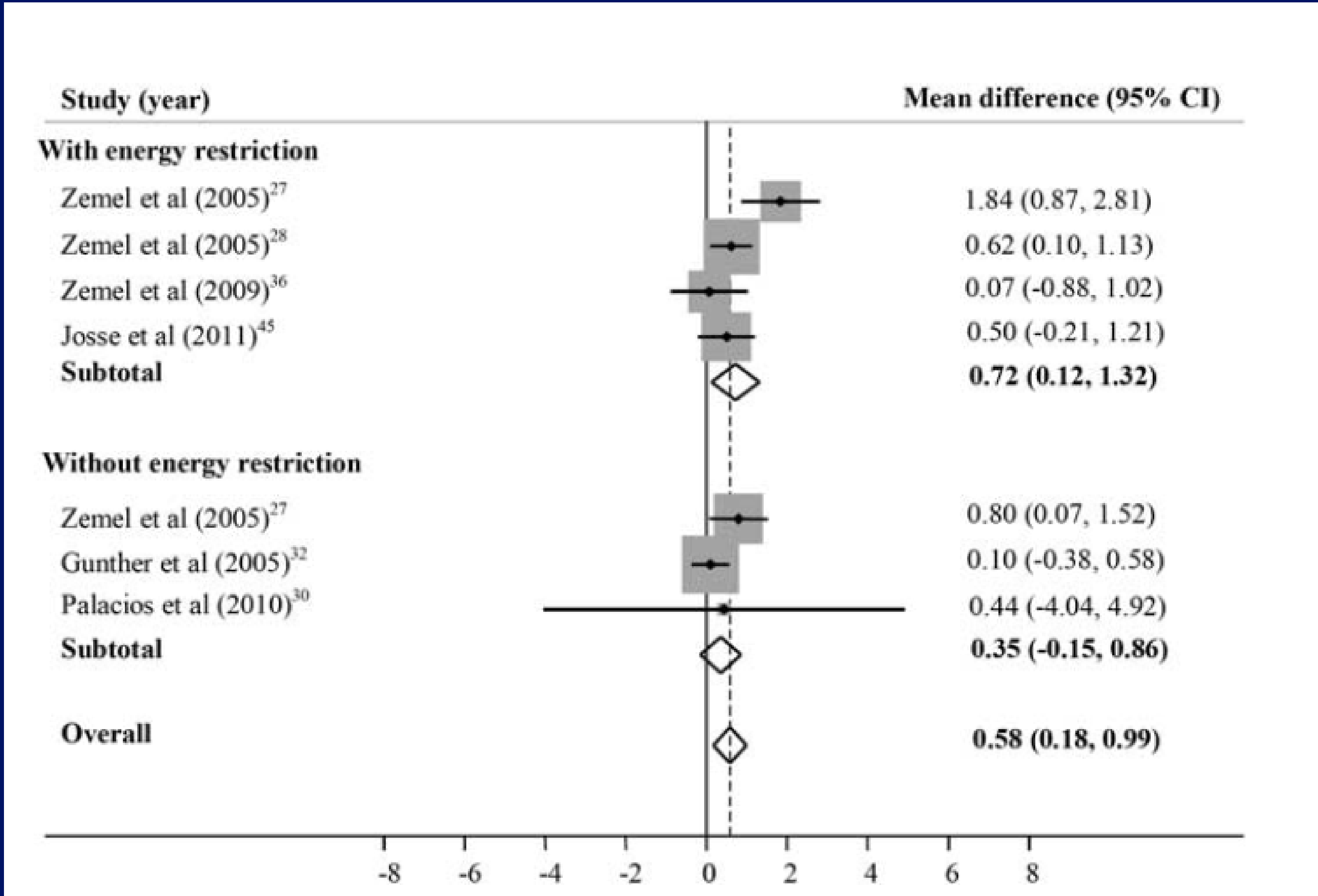
Effects



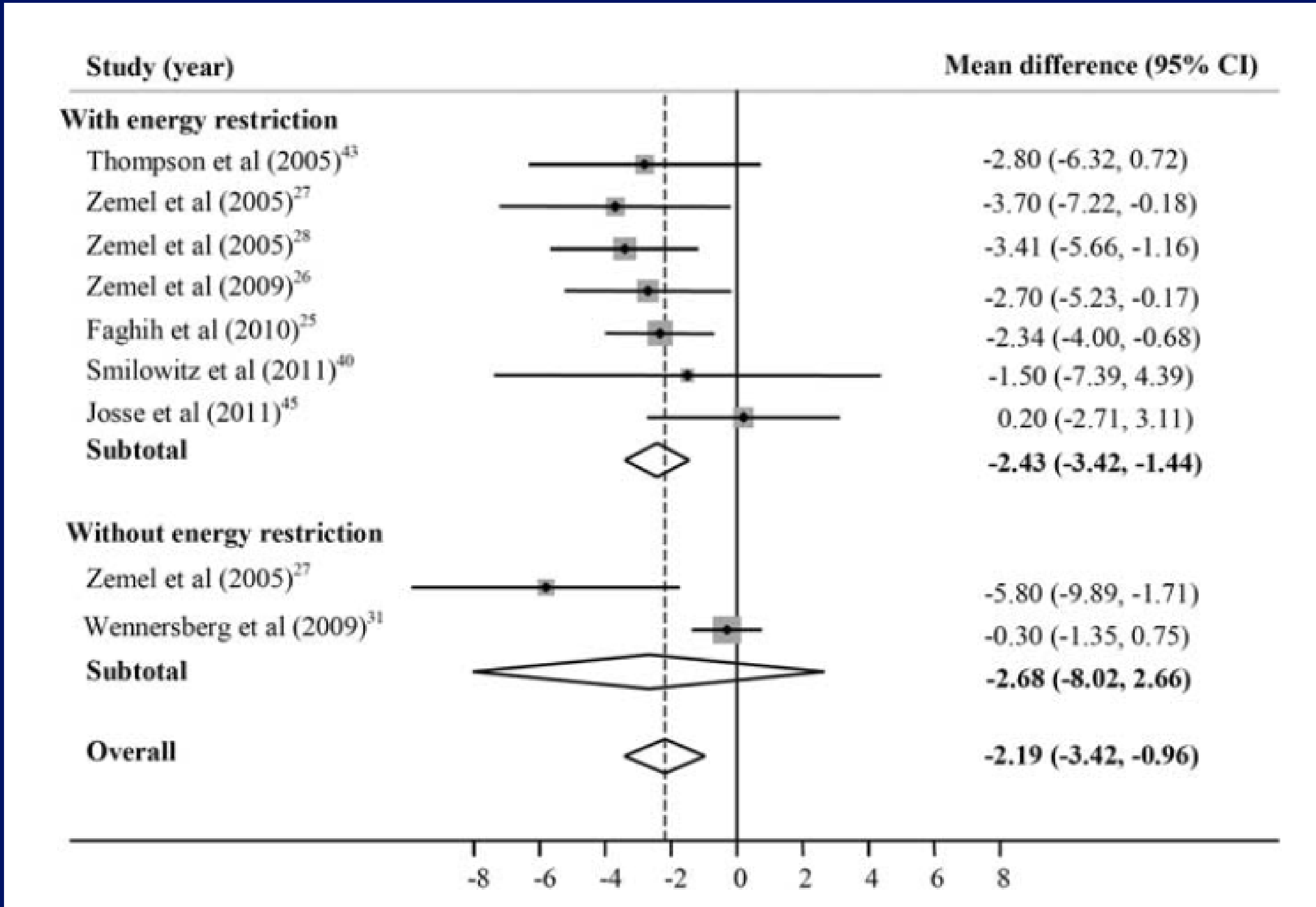
# Effect of high vs low dairy on fat loss



# Effect of high vs low dairy on fat free mass



# Supplementation with dairy



# Conclusions

- Dairy (low-fat) products have beneficial effects on energy balance for prevention and treatment of obesity
- Protein exerts a high satiating and thermogenic effect
- Calcium binds dietary fat in GI tract AND this malabsorption contributes to
- A negative energy balance
- A reduced postprandial lipidemia
- A reduction in LDL-cholesterol while
- maintaining a high HDL-cholesterol
- A low calcium intake may trigger hunger and impair weight loss during energy restricted diets.

# Thank you

Study funding:
Danish Research Council (FØSU),
Danish Dairy Research Foundation,
Arla Foods,
Dutch Dairy Association (NZO),
BBC

-Also to my coworkers:

-Assistent professor Janne Lorenzen

-Assistent professor Nathalie T Bendsen