Effects of low calorie-sweeteners on energy intake and weight management

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University of Bristol

ILSI-India Conference on Sweetness: Role of Sugar & Low Calorie Sweeteners
New Delhi, 20th September 2017

Disclosures

- I have received funding for research from Sugar Nutrition UK, provided consultancy services for Coca-Cola Great Britain and received speaker's fees from the International Sweeteners Association and the Global Stevia Research Institute.
- I will be referring to a systematic review and meta-analyses of effects of low-calorie sweeteners on energy intake and body weight. This review was initiated by ILSI-Europe, who also provided administrative support, hosted meetings of the authors, and paid the academic authors travel expenses and honoraria. Two of the eleven authors of the review are food industry employees, and one was an ILSI-Europe employee.

Affective responses to basic tastes (Jacob Steiner, 1987)

We are born liking sweetness

Low-calorie sweeteners = calorie-free pleasure

Too good to be true?

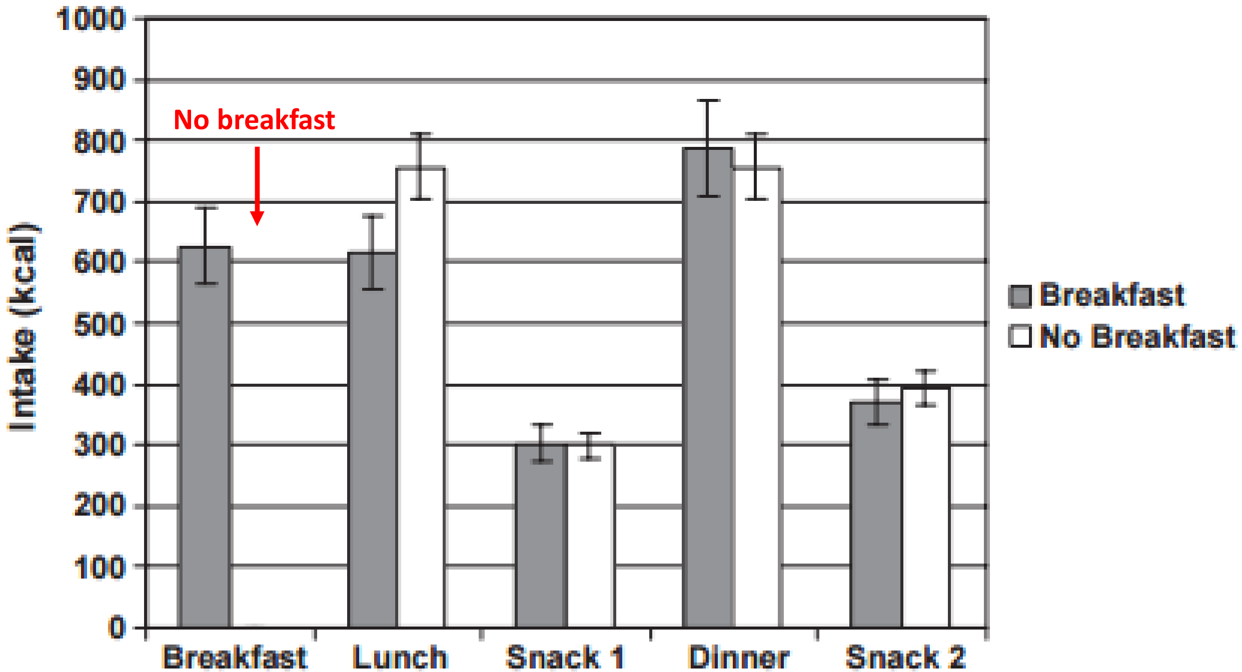
zero kcal

210 kcal

Low-calorie sweeteners: are they helpful in appetite and weight control?

- By replacing all or some sugar, low-calorie sweeteners reduce the energy content of foods and especially drinks
- And reduced energy intake in a meal or snack is not fully compensated for by increased energy intake at the next or subsequent meals or snacks

How to decrease energy intake – miss a meal

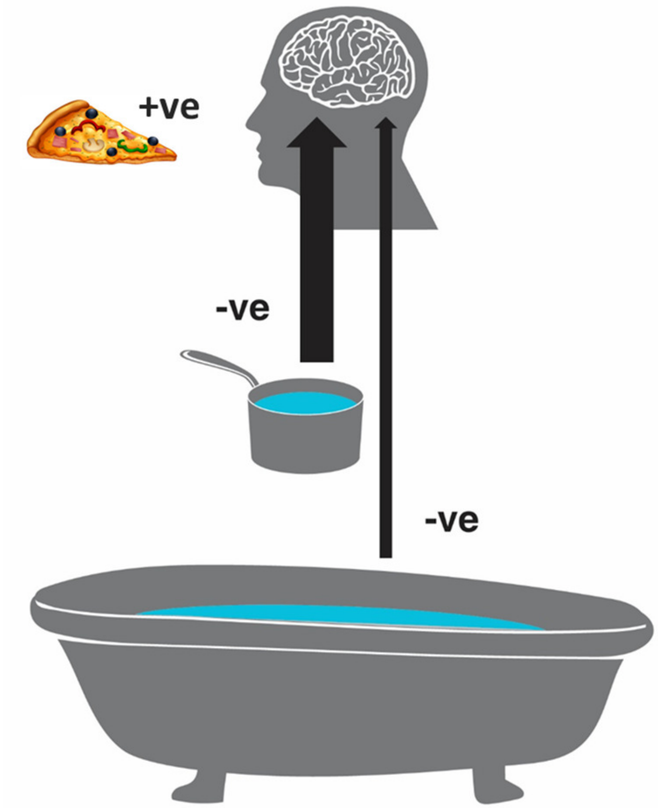


After missing 625 kcal breakfast
Lunch intake ↑ 135 kcal
Total day intake ↓ 495 kcal

Levitsky D. A. (2005) *Physiology and Behavior, 86, 623-632*

An analogy for human appetite control

- Body energy stores (bath tub) are replenished via the gut (saucepan)
- Ratio of energy content of an average meal to available body energy stores is conservatively about 1:200
- So missing a meal can be expected to have a trivial effect on energy supply to the brain and muscle
- Both the gut and body fat stores resist being filled proportional to their contents (negative feedbacks)
- We eat because eating is rewarding (pleasurable). Eating is more rewarding when we like the food and our gut is empty



Rogers P. J. & Brunstrom J. M. (2016) *Physiology and Behavior, 164*, 465-471

Low-calorie sweeteners: are they helpful in appetite and weight control?

- By replacing all or some sugar, low-calorie sweeteners reduce the energy content of foods and especially drinks
- On the other hand it has been claimed that consumption of low-calorie sweeteners may
  - confuse the relationship between sweet taste and calories (and thereby increase sugar and energy intake)
  - increase desire for sweetness (and thereby increase sugar and energy intake)
  - cause consumers to consciously over-compensate for the 'calories saved'

Sweet taste as a predictor of food energy (sugar) content

(1) 'We reasoned that if sweet tastes are normally valid predictors of increased caloric outcomes,*

(2) then exposing rats to sweet taste that is not associated with these outcomes should degrade this predictive relationship

(3) and impair energy intake and body weight regulation.'

*'In nature, and throughout most of our evolutionary history, sweetness has been a reliable predictor of the energy content of food.' (Swithers et al., 2010, p 56)

Swithers et al. (2010) *Physiology and Behavior, 100,* 55-62

Sweet taste as a predictor of food energy (sugar) content

High-intensity sweeteners and energy balance

Susan E. Swithers *, Ashley A. Martin, Terry L. Davidson

Department of Psychological Sciences, Purdue University, West Lafayette, IN, USA

Physiology & Behavior 100 (2010) 55–62

Unsweetened yogurt 3 d/wk

Sweetened yogurt 3 d/wk

Non-predictive (of additional calories) = Saccharin

OR

Predictive (of additional calories) = Glucose

Rat chow ad libitum

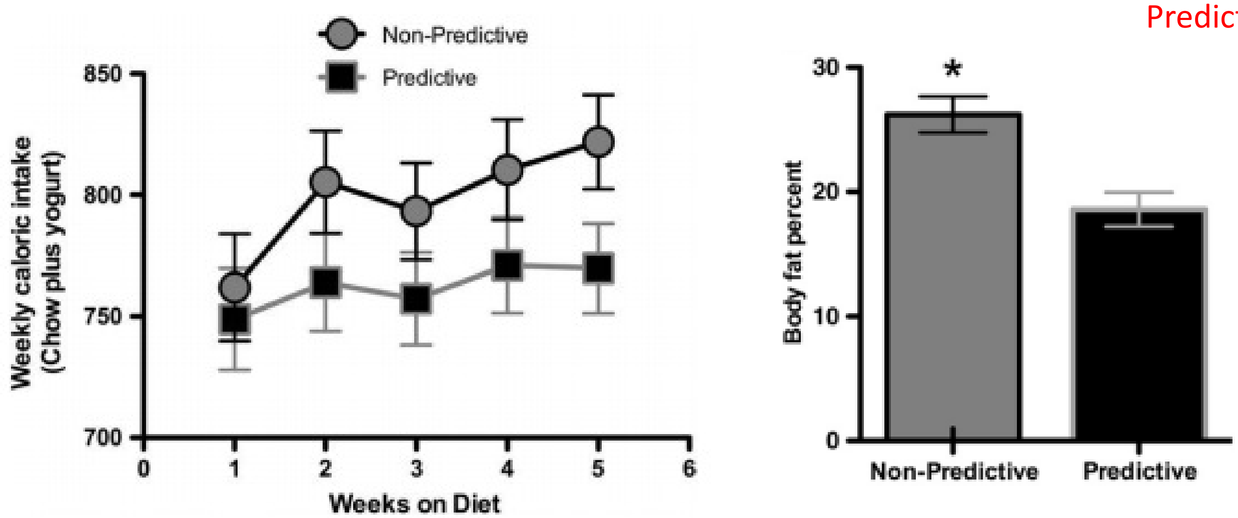
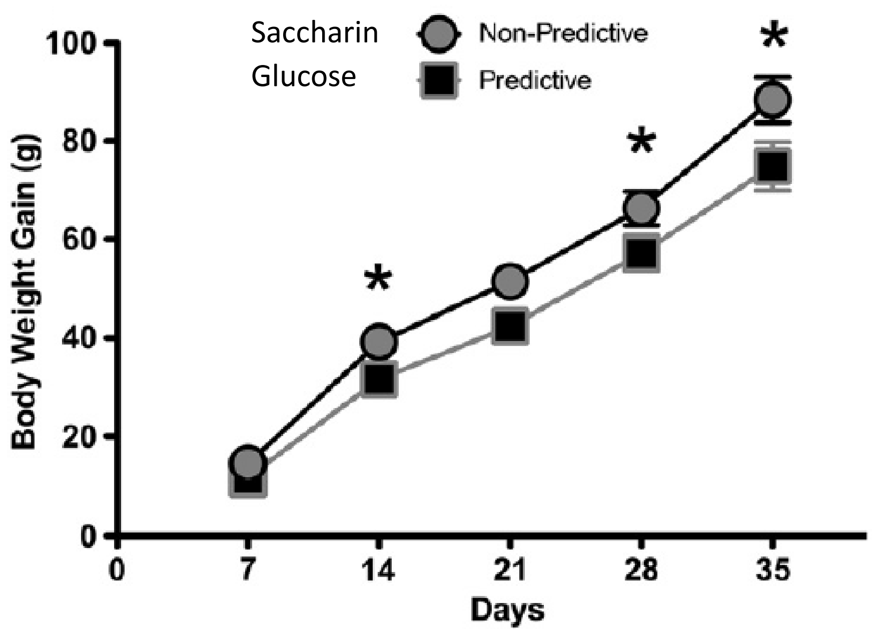
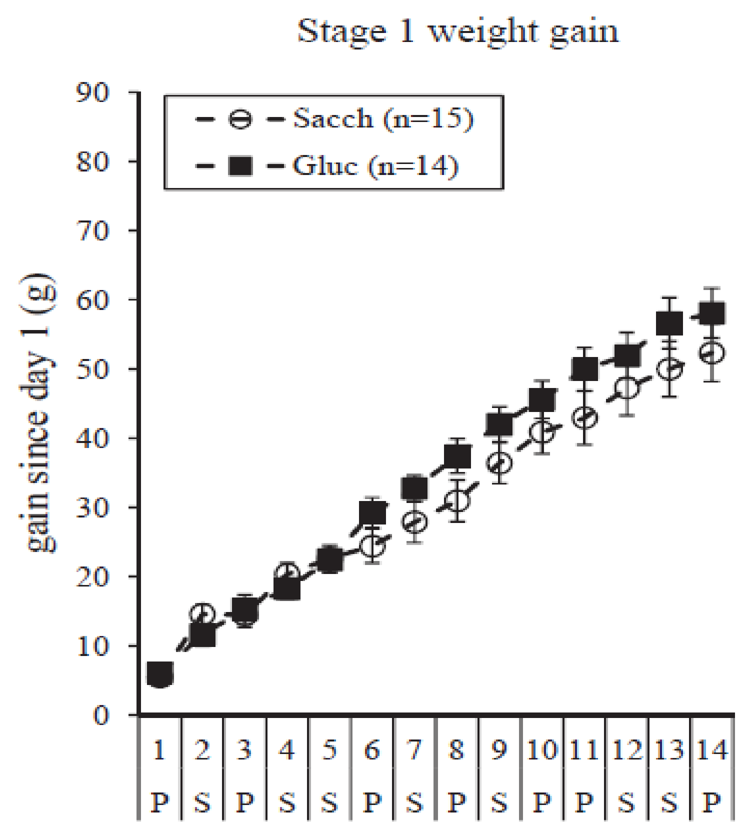


Fig. 2. Total caloric intake tended to be greater in rats given access to saccharin-sweetened yogurt diet supplements in which sweet taste did not predict increased calories (Non-Predictive group) compared to animals given glucose-sweetened yogurt diet supplements (Predictive group) in which sweet taste did reliably predict increased calories (ns = 8–9 per group).

Sweet taste as a predictor of food energy (sugar) content



Swithers et al. (2010) *Physiology and Behavior, 100,* 55-62



Boakes et al. (2016) *Appetite, 105,* 105-128

Sweet taste predicts the sugar but not the energy content of foods and drinks

Correlations between sweetness and sugar and energy content of foods and drinks in three studies

	Sugar	Energy	Reference
Australia	.70	-.08	1
Netherlands	.67	not reported	2
United States	.70	.11	3

1. Lease et al. (2016) *Food Quality and Preference, 49,* 20-32
2. Van Dongen et al. (2012) *British Journal of Nutrition, 108,* 140-147
3. van Langveld et al. (2017) *Food Quality and Preference, 57,* 1-7

Sugar content does not predict the energy content of 'natural' foods

Energy, sugar and total carbohydrate content per 100 g of some 'natural' (i.e., minimally processed) carbohydrate-rich foods

	Energy, kcal	Sugar, g	Total CHO, g
Fresh fruits and berries, n=7	58	10.3	14.4
Roots and tubers, n=8	78	3.1	17.9
Grains, n=4	121	1.0	25.2

<u>Some individual fruits, per 100 g</u>
Strawberry = 5 g sugar, 33 kcal
Blueberry = 10 g sugar, 57 kcal
Grape = 16 g sugar, 67 kcal

Sweet taste as a predictor of food energy (sugar) content

(1) ‘We reasoned that if sweet tastes are normally valid predictors of increased caloric outcomes,* [THIS IS NOT TRUE]

(2) then exposing rats to sweet taste that is not associated with these outcomes should degrade this predictive relationship

(3) and impair energy intake and body weight regulation.’

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- By replacing all or some sugar, low-calorie sweeteners reduce the energy content of foods and especially drinks
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Does consumption of low-calorie sweeteners increase or decrease desire for sweetness?

Thus, repeated exposure to NNS (non-nutritive sweeteners) would be expected to establish and maintain a preference for sweet items in the diet.

Mattes & Popkin (2009) *American Journal of Clinical Nutrition, 89,* 1-14

"In addition, overstimulation of sugar receptors by frequent consumption of hyper-intense sweeteners may cause taste preferences to remain in, or revert to, an infantile state (i.e., with limited tolerance to more complex tastes)."

Ludwig, D.S. (2009) *Journal of the American Medical Association, 302,* 2477-8

Lastly, artificial sweeteners, precisely because they are sweet, encourage sugar craving and sugar dependence. Repeated exposure trains flavor preference [54]. A strong correlation exists between a person's customary intake of a flavor and his preferred intensity for that flavor. Systematic reduction of dietary salt [55] or fat [56] without any flavorful substitution over the course of several weeks led to a preference for lower levels of those nutrients in the research subjects. In light of these findings, a similar approach might be used to reduce sugar intake. Unsweetening the world's diet [15] may be the key to reversing the obesity epidemic.

Yang, Q. (2010) *Yale Journal of Biology and Medicine, 83,* 101-8

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And/or Sensory-Specific Satiety?

Hetherington M.M. et al. (1989) The time course of sensory-specific satiety. *Appetite, 12,* 57-68.

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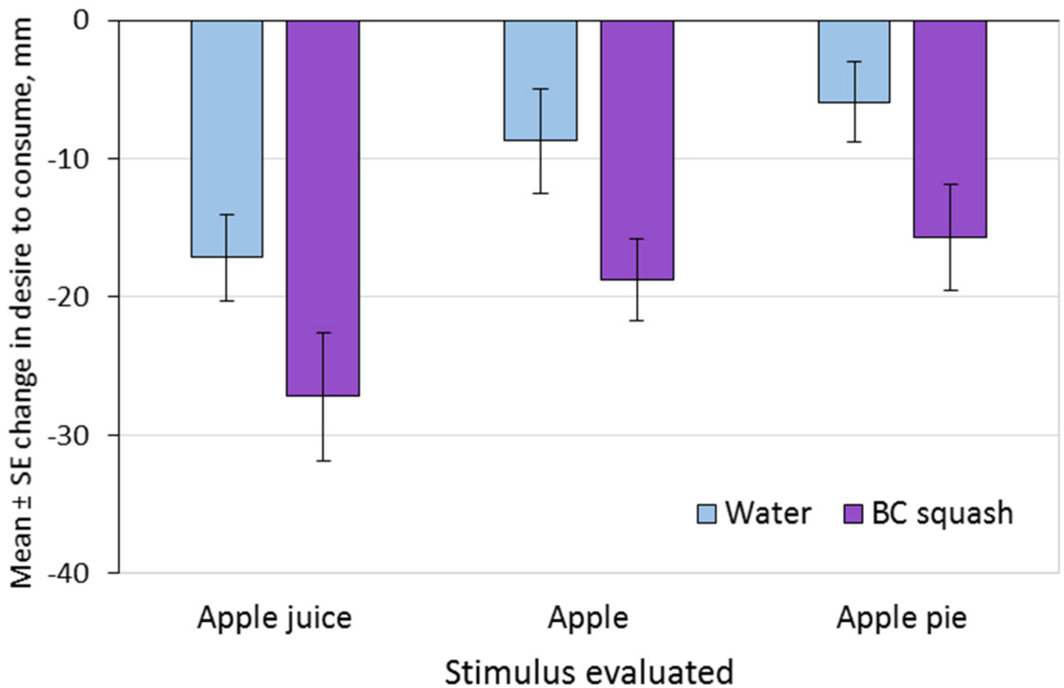
Does consumption of low-calorie sweeteners increase or decrease desire for sweetness?

Effect of consuming a non-sweet drink (water) versus sweet drink (low-calorie blackcurrant squash) on desire to consume apple juice, fresh apple and apple pie

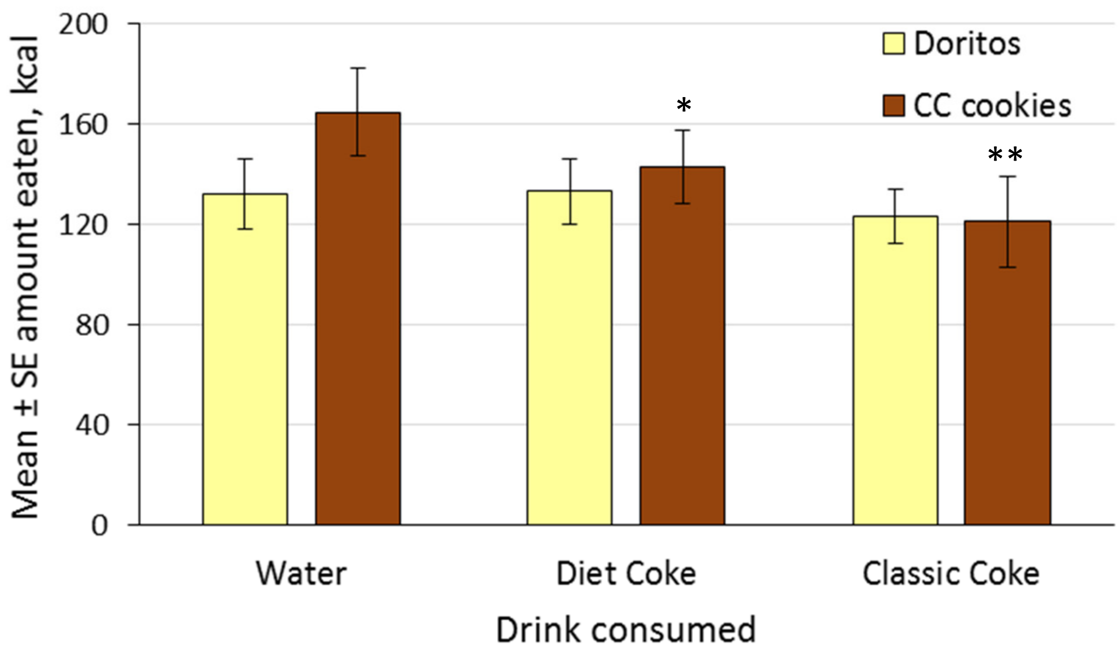


Effect of Drink, p=.003
Effect of Stimulus, p=.002
Drink x Stimulus, F<1

Rogers et al., in preparation

Does consumption of low-calorie sweeteners increase or decrease desire for sweetness?

Effect of consuming sweet drinks on sweet and savoury food intake



Cross-over design
Participants consumed the drink with a sandwich and with the subsequently presented Doritos (savoury) and chocolate chip cookies (sweet)

*p<.05, **p<.01, vs water

Rogers et al., in preparation

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Is there conscious over-compensation for the energy reduction achieved with low-calorie sweeteners?

INFORMED USE LEADS TO OVERCOMPENSATION

Nutrient labeling allows consumers to make informed decisions about the nutritive quality of their diet, but this may be counterproductive if the information is not correctly interpreted. Labeling foods as lower in energy could lead consumers to alter their feeding behavior and paradoxically increase their energy intake. This may occur if the expected savings in energy attributed to the substitution of an energy-diluted product is greater than any subsequent indulgence rationalized by the prior savings.

Mattes & Popkin (2009) *American Journal of Clinical Nutrition, 89,* 1-14

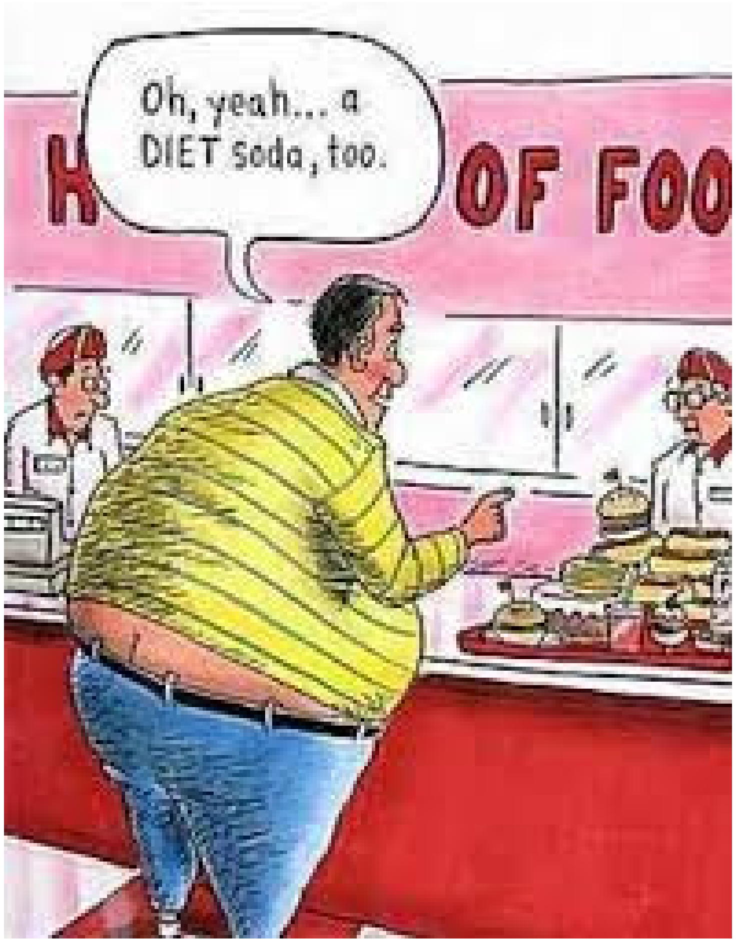
Studies comparing the effect of LCS vs sugar on energy intake in participants informed vs not informed about sweetener and/or calorie content

Authors and year of publication	Number of participants	Duration of intervention	Effect of information*
Rolls et al., 1989	16	< 1 day	No effect
Mattes, 1990	24	5 days	Weak evidence for information increasing energy intake in LCS vs sugar condition
Rogers et al., 1990	41	< 1 day	No effect
Lavin et al., 1997	14	1 day	No effect
Reid et al., 2007**	133	4 weeks	No effect

*Effect of information on the difference in energy intake between LCS and sugar conditions

**In this study half the participants were correctly and half were incorrectly informed (‘diet’ vs ‘sugar’)

Is there conscious over-compensation for the energy reduction achieved with low-calorie sweeteners?



No such effect revealed by the few relevant studies done on this to date

Low-calorie sweeteners: are they helpful in appetite and weight control?

- Evidence from trials on effects of low-calorie sweeteners on energy intake and body weight

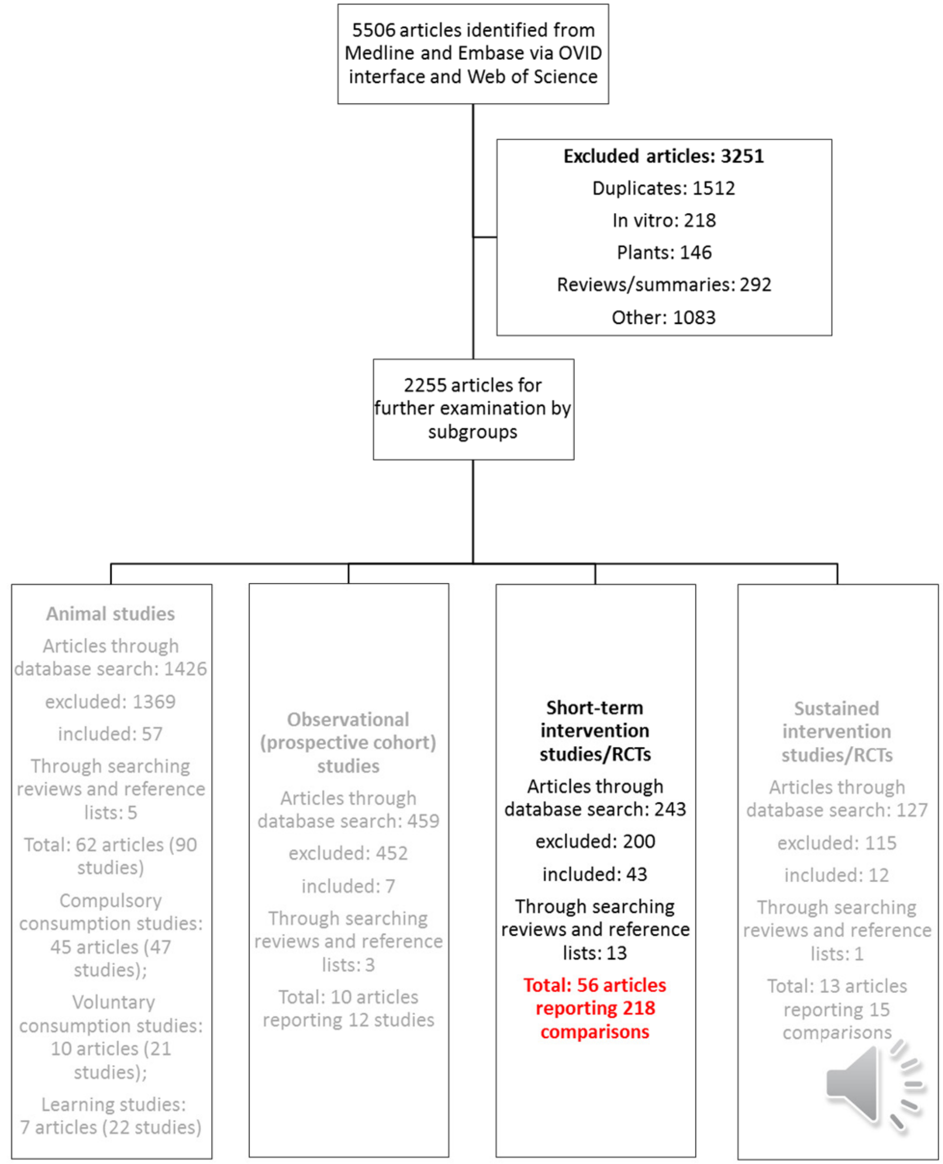
International Journal of Obesity

Does low-energy sweetener consumption affect energy intake and body weight? A systematic review, including meta-analyses, of the evidence from human and animal studies

OPEN

P J Rogers[1], P S Hogenkamp[2], K de Graaf[3], S Higgs[4], A Lluch[5], A R Ness[6], C Penfold[6], R Perry[6], P Putz[7], M R Yeomans[8] and D J Mela[9]

International Journal of Obesity (2016) 40, 381-394

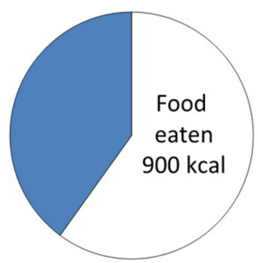


Short-term effects of low-calorie sweeteners on energy intake

‘Preload’

= <1 kcal

‘Test meal’
1500 kcal served



Total energy intake

900 kcal

Illustrative results based Rogers et al. (2016) *International Journal of Obesity,* 40, 381-394

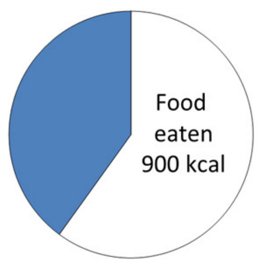
Short-term effects of low-calorie sweeteners on energy intake

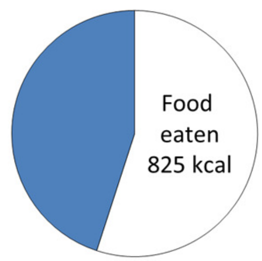
'Preload'

= <1 kcal

150 kcal

'Test meal'
1500 kcal served



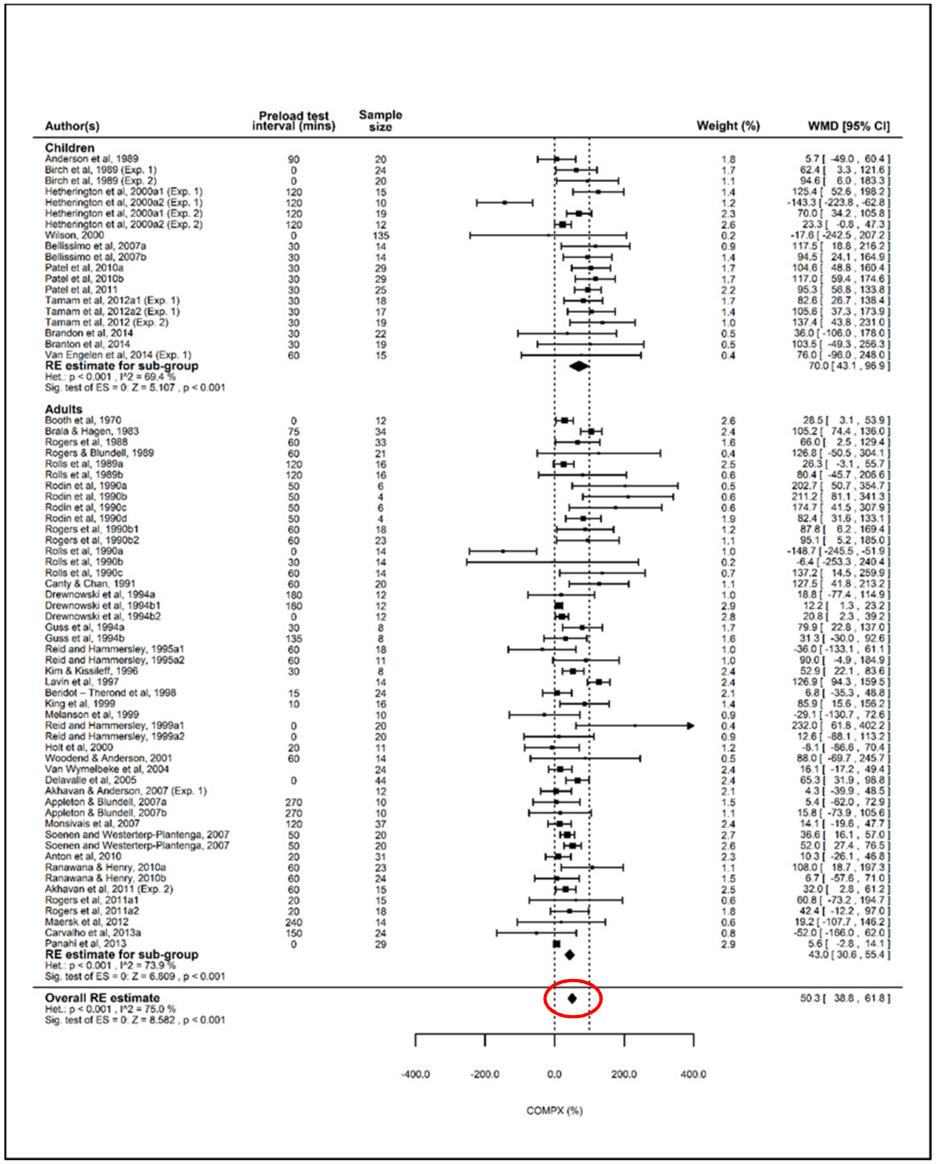


Total energy intake

900 kcal

975 kcal
'Compensation'
= 50%

Illustrative results based Rogers et al. (2016) *International Journal of Obesity,* 40, 381-394



Details of short-term intervention studies results: 'compensation' (COMPX) scores

Preload, test-meal studies showed:

- Reduced energy intake versus sugar (70% compensation in children) (43% compensation in adults) (50% compensation overall)

Rogers et al. (2016)
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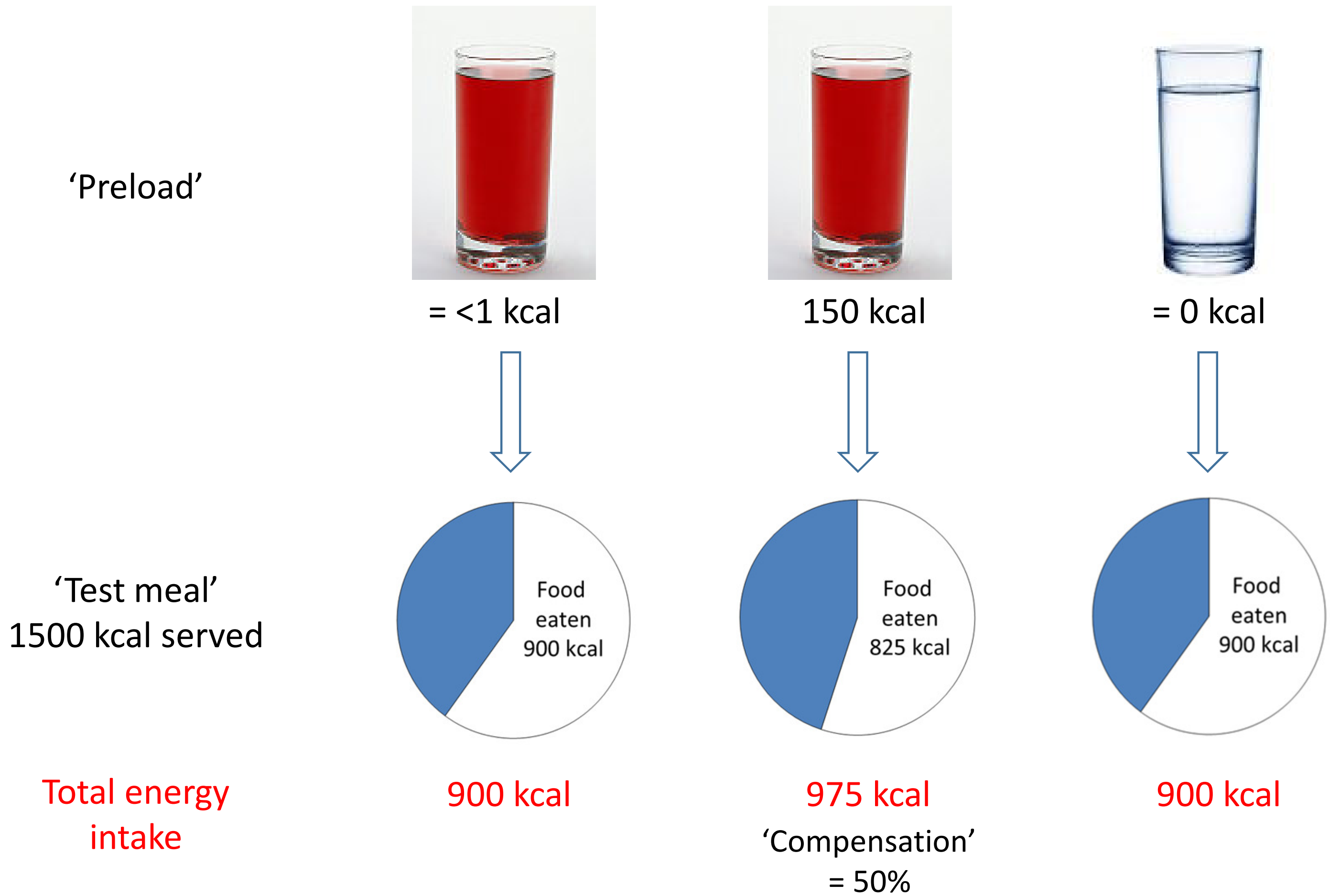
Short-term effects of low-calorie sweeteners on energy intake



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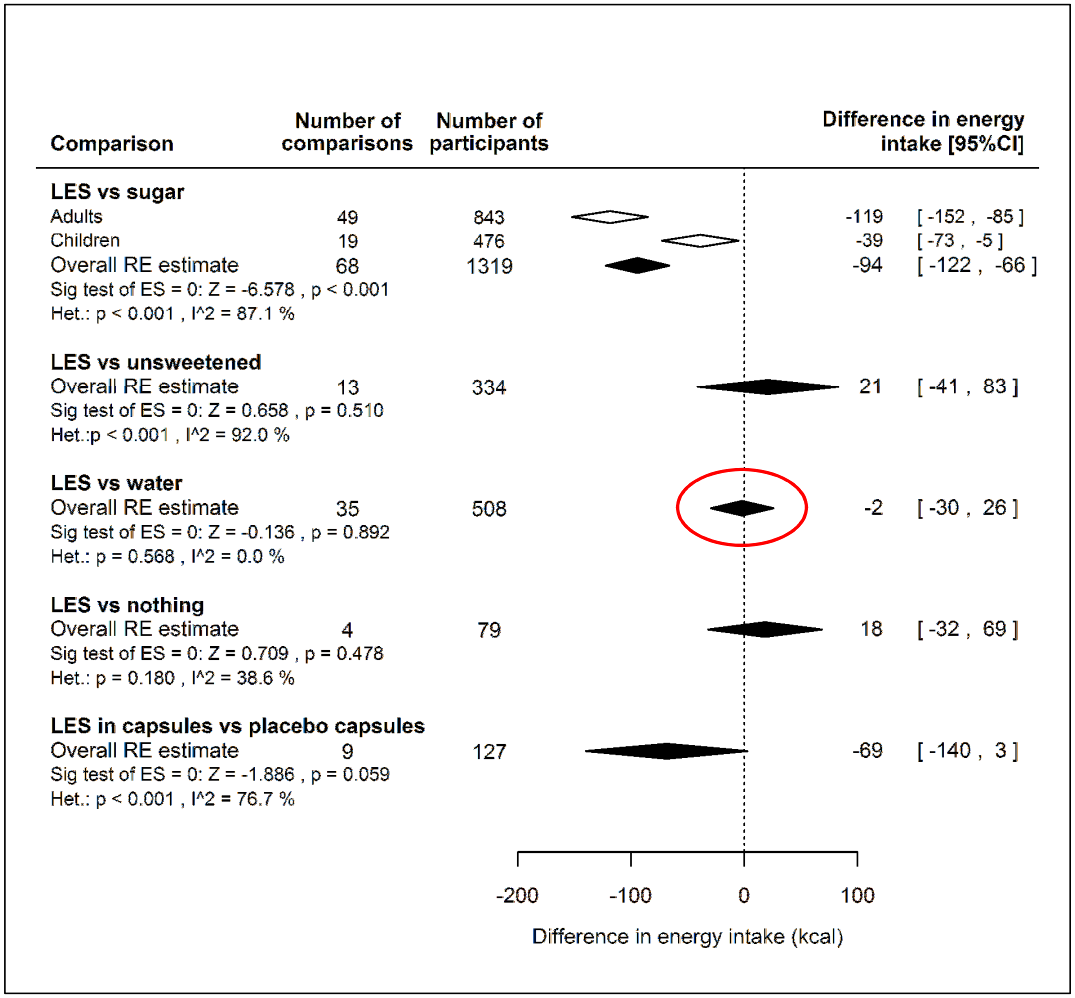
Short-term effects of low-calorie sweeteners on energy intake



Preload, test-meal studies showed:

- Reduced energy intake after LCS versus sugar
- No effect on energy intake after LCS versus water

Rogers et al. (2016)
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Does low-energy sweetener consumption affect energy intake and body weight? A systematic review, including meta-analyses, of the evidence from human and animal studies

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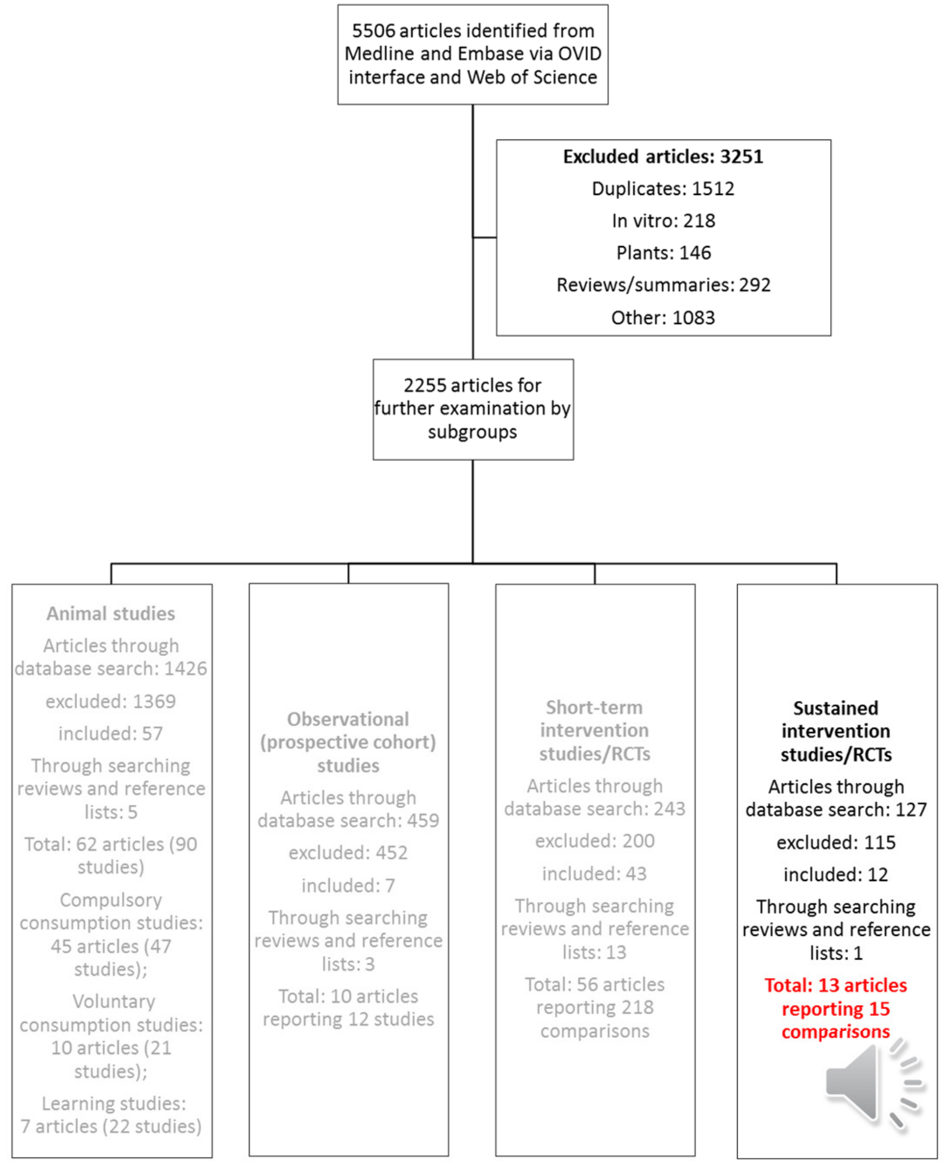


Sustained intervention studies: effects of low-calorie sweeteners versus sugar on body weight

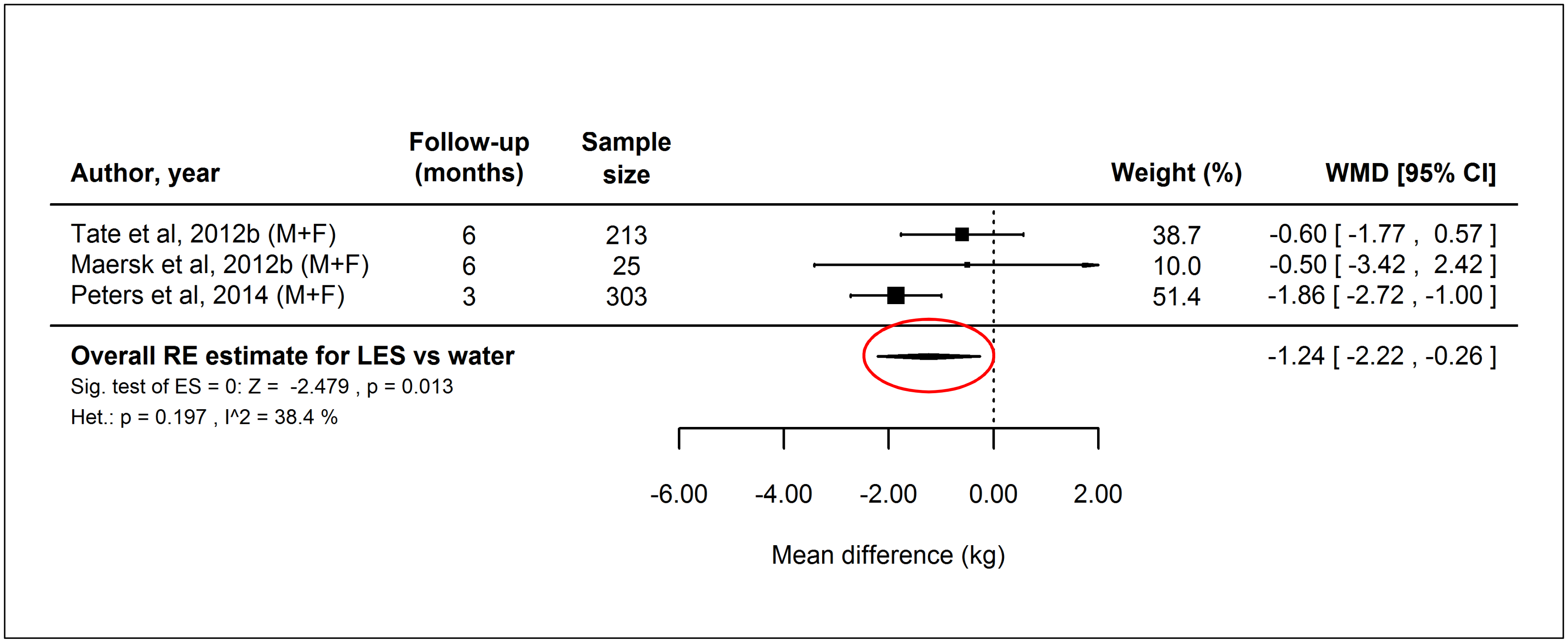
Author, year	Follow-up (months)	Sample size	Weight (%)	WMD [95% CI]
Adults				
Kanders et al, 1988 (M+F)	3	59	7.4	-0.40 [-2.75 , 1.95]
Blackburn et al, 1997 (F)	40	163	11.5	-5.10 [-6.29 , -3.91]
Raben et al, 2002 (M+F)	2.5	41	11.8	-2.60 [-3.71 , -1.49]
Reid et al, 2007 (F)	1.25	66	12.4	-0.45 [-1.39 , 0.49]
Njike et al, 2009 (M+F)	6	77	13.9	-0.09 [-0.49 , 0.31]
Reid et al, 2010 (M+F)	1.25	53	11.9	-0.49 [-1.58 , 0.60]
Tate et al, 2012a (M+F)	6	210	11.8	-0.80 [-1.90 , 0.30]
Maersk et al, 2012a (M+F)	6	22	5.6	-1.20 [-4.25 , 1.85]
RE estimate for adult subgroup				-1.41 [-2.62 , -0.20]
Children				
de Ruyter et al, 2012 (M+F)	18	641	13.7	-1.02 [-1.52 , -0.52]
Overall RE estimate for LES vs sugar-sweetened beverages				-1.35 [-2.28 , -0.42]

Adult subgroup: Sig. test of ES = 0: Z = -2.280 , p = 0.023; Het.: p < 0.001 , I^2 = 90.5 %

Overall: Sig. test of ES = 0: Z = -2.854 , p = 0.004; Het.: p < 0.001 , I^2 = 89.2 %

Rogers et al. (2016) *International Journal of Obesity*, 40, 381-394

Sustained intervention studies:
effects of low-calorie sweeteners versus water on body weight



Rogers et al. (2016) *International Journal of Obesity,* 40, 381-394

Does diet-beverage intake affect dietary consumption patterns? Results from the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial[1–3]

Carmen Piernas, Deborah F Tate, Xiaoshan Wang, and Barry M Popkin

Participants randomised to choose **water** (n=106) or **diet beverages** (n=104) in place of sugar-sweetened beverages for 6 months.

Conclusions: Participants in both intervention groups showed positive changes in energy intakes and dietary patterns. The DB group showed decreases in most caloric beverages and specifically reduced more desserts than the water group did. Our study does not provide evidence to suggest that a short-term consumption of DBs, compared with water, increases preferences for sweet foods and beverages. This trial was registered at clinicaltrials.gov as NCT01017783. *Am J Clin Nutr* 2013;97:604–11.

Conclusions

- By replacing all or some sugar, low-calorie sweeteners reduce the energy content of foods and especially drinks – leading to reduced energy intake and body weight
- On the other hand it has been claimed that consumption of low-calorie sweeteners may
  - confuse the relationship between sweet taste and calories (and thereby increase sugar and energy intake) – (1) no evidence for this in humans, (2) there are logical problems with this argument, and (3) the relevant results from animal studies have been disputed
  - increase desire for sweetness (and thereby increase sugar and energy intake) – if anything, in the short-term, exposure to a sweet drink decreases desire and intake of sweet food
  - cause consumers to consciously over-compensate for the 'calories saved' – no evidence for this

Thank You

Prof. Peter Rogers

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