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Systematic Review with Meta-Analysis

Effect of increasing dietary calcium through supplements and dairy food on body weight and body composition: a meta-analysis of randomised controlled trials

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Abstract
This meta-analysis of randomised controlled trials assessed the effect of Ca on body weight and body composition through supplementation or increasing dairy food intake. Forty-one studies met the inclusion criteria (including fifty-one trial arms; thirty-one with dairy foods (*n* 2091), twenty with Ca supplements (*n* 2711). Ca intake was approximately 900 mg/d higher in the supplement groups compared with control. In the dairy group, Ca intake was approximately 1300 mg/d. Ca supplementation did not significantly affect body weight (mean change (−0·17, 95 % CI −0·70, 0·37) kg) or body fat (mean change (−0·19, 95 % CI −0·51, 0·13) kg) compared to control. Similarly, increased dairy food intake did not affect body weight (−0·06, 95 % CI −0·54, 0·43) kg or body fat change (−0·36, 95 % CI −0·80, 0·09) kg compared to control. Sub-analyses revealed that dairy supplementation resulted in no change in body weight (nineteen studies, *n* 1010) (−0·32, 95 % CI −0·93, 0·30 kg, $P=0·31$), but a greater reduction in body fat (thirteen studies, *n* 564) (−0·96, 95 % CI −1·46, −0·46 kg, $P<0·001$) in the presence of energy restriction over a mean of 4 months compared to control. Increasing dietary Ca intake by 900 mg/d as supplements or increasing dairy intake to approximately 3 servings daily (approximately 1300 mg of Ca/d) is not an effective weight reduction strategy in adults. There is, however, an indication that approximately 3 servings of dairy may facilitate fat loss on weight reduction diets in the short term.

Key words: **Calcium: Body weight: Body composition: Meta-analysis**

Approximately 1·6 billion adults are overweight globally and 400 million of these are obese[1,2]. Obesity can lead to serious health consequences, including CVD, type 2 diabetes and some cancers, which places considerable burden on health services. Weight reduction can improve the health of overweight individuals. Even modest reduction of 5 % in body weight (3 kg with a body weight of 65 kg) can significantly reduce the risk of disease[3]. While it is generally accepted that energy balance plays the major role in weight management, an increasing number of studies have explored the potential role of Ca in weight loss[4–8]. The results of several cross-sectional epidemiological studies have indicated that dietary Ca may be associated with lower body weight and/or adiposity, such that a diet rich in Ca may attenuate weight gain[6,9–11]. Possible mechanisms have also been explored[6,12] and include the potential to increase fecal fat excretion[13,14], the suppression of calcitriol levels[15] and improving insulin sensitivity[16,17], which has been related to reducing fat deposition. Few randomised controlled trials have been undertaken to specifically investigate if increasing dietary Ca reduces body weight[4,8,18,19].

This review comprehensively and systematically analyses the available evidence assessing the effects of dairy and added Ca supplementation on body weight. This extends an earlier systematic review of thirteen studies published up to 2004[7], which found no significant effect of Ca on weight loss. Since 2004, several additional published studies have reported on the effects of increased Ca intake (through Ca or dairy supplementation) on changes in body weight and/or body composition, including twenty-seven randomised controlled trials with 4000 participants. Whilst there has been three subsequent reviews[20–22], these have limited

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generalisability due to the strict inclusion criteria. Onakpoya *et al.*[20] conducted a meta-analysis on a subset of seven studies, each providing Ca supplementation that had body weight as the primary outcome and found that Ca supplementation resulted in a small but significant reduction in body weight and body fat. However, this study excluded several studies (total of 1963 participants) that had bone health or other factor as a primary outcome. In contrast, two meta-analyses have been published since 2012 on dairy food supplementation and body weight and found no overall effect on body weight in the long term[21,22]. The limitations of these reviews include the narrow selection of included studies (half of available published studies)[21]; and inclusion of studies with intervention periods of very short duration (<12 weeks' duration)[22]. This systematic review encompasses a broader range of studies with the aim of addressing these limitations. Meta-analysis was used to determine if increased Ca in the form of Ca supplementation or increased dairy food intake consumed for at least 12 weeks leads to a decrease in body weight.

Methods

Literature search

Electronic databases Medline, EMBASE and CINAHL were searched from 1994 to December 2014 as well as the Complete Cochrane Library Database of Controlled Trials from 1800 (earliest record) to December 2014. Search terms included 'calcium' or 'dairy' with 'weight' or 'composition' or 'fat'. These terms encompassed 'calcium supplement(s)', 'calcium supplementation', 'dairy products', 'milk', 'cheese', 'yoghurt', 'body weight', 'body fat' and 'body composition' (online Supplementary Fig. S1). Only articles published in full length and in English were selected.

Study quality, inclusion and exclusion criteria

Inclusion criteria included: randomised controlled trial of Ca supplements or increased dairy products and intervention in adults over the age of 18 years that assessed changes in body weight, with or without data on body composition. To ensure quality of included studies, studies were only included if the intervention length was at least 12 weeks; Ca supplementation was of at least 300 mg/d; increased dairy intake provided an increase of at least 300 mg of Ca/d; and Ca intake was at least 300 mg higher than the control group. Studies in which the Ca was supplemented in the form of non-dairy-based fortified foodstuffs or powder were included in the same category as Ca supplements. Studies in pregnant or lactating women were excluded as well as populations with severe illnesses such as cancer.

Study selection

A summary of study selection and exclusion is outlined in Fig. 1. Abstracts were reviewed independently by at least two reviewers (including C. E. H., N. W. and A. O. B.). Any disputes were assessed by a fourth reviewer (C. A. N.).

Five studies were excluded that did not report body weight at two time points[23–28] and one[23–28] reported in graph format that could not be estimated. Two of these studies[29,30] reported body weight at study completion in related studies already found in the initial search and were included in the analysis. Of the remaining four studies that reported body weight at baseline but not study completion, authors were contacted for data to include in the analysis and one author was able to provide the relevant data on body weight[23]; thus, this study was added back into the included studies. Twenty-nine studies with thirty-two trial arms provided information on body composition.

Data extraction

Relevant data were extracted and, wherever necessary, weight was converted and reported as kg. Where mean changes were reported graphically with variance[31], the graph was magnified 600× and values were estimated by the authors (N. W.). Where studies reported data separately for males and females, the data were combined[32,33]. For studies that reported body weight at exit, change from baseline standard deviation was imputed using a correlation coefficient[34] (Cochrane Handbook for Systematic Reviews of Interventions 16.1.3.2)[32]. Where mean change data were not reported in the required format, the authors were contacted[6]. A correlation value of r 0·6 was used as it is considered a conservative estimate of correlation between baseline and end body weights.

Statistical analysis

Review Manager (RevMan, version 5.3) was used to conduct meta-analyses with the change in body weight (kg) and body fat (kg) as the outcome. Separate analyses were conducted by intervention type: dairy food or Ca supplement. Subgroup analysis was performed for studies that included dietary energy restriction. Where variance was reported as SE or CI, SD was calculated. Random effects models in which the trials were assumed to be a random sample from a population of trials (both actual and potential) were used[35]. All treatment effects are presented with 95 % CI. A funnel plot was used to detect the possibility of publication bias, and Egger's regression test[36] to measure funnel plot asymmetry was performed using SAS (version 9.3; SAS Institute, Inc.).

Results

Forty-one studies were identified that met the inclusion criteria. Of these, ten used Ca supplementation only, twenty-five used dairy product supplementation only and six used both Ca and dairy product supplementation. Study characteristics are summarised in Table 1 (Ca supplementation) and Table 2 (dairy product supplementation). Of the forty-one studies, fifty-one intervention trial arms were included; in thirty-three studies, two trial arms were included (intervention, control); in six studies, three trial arms were included (one dairy intervention group, one Ca supplement group and a

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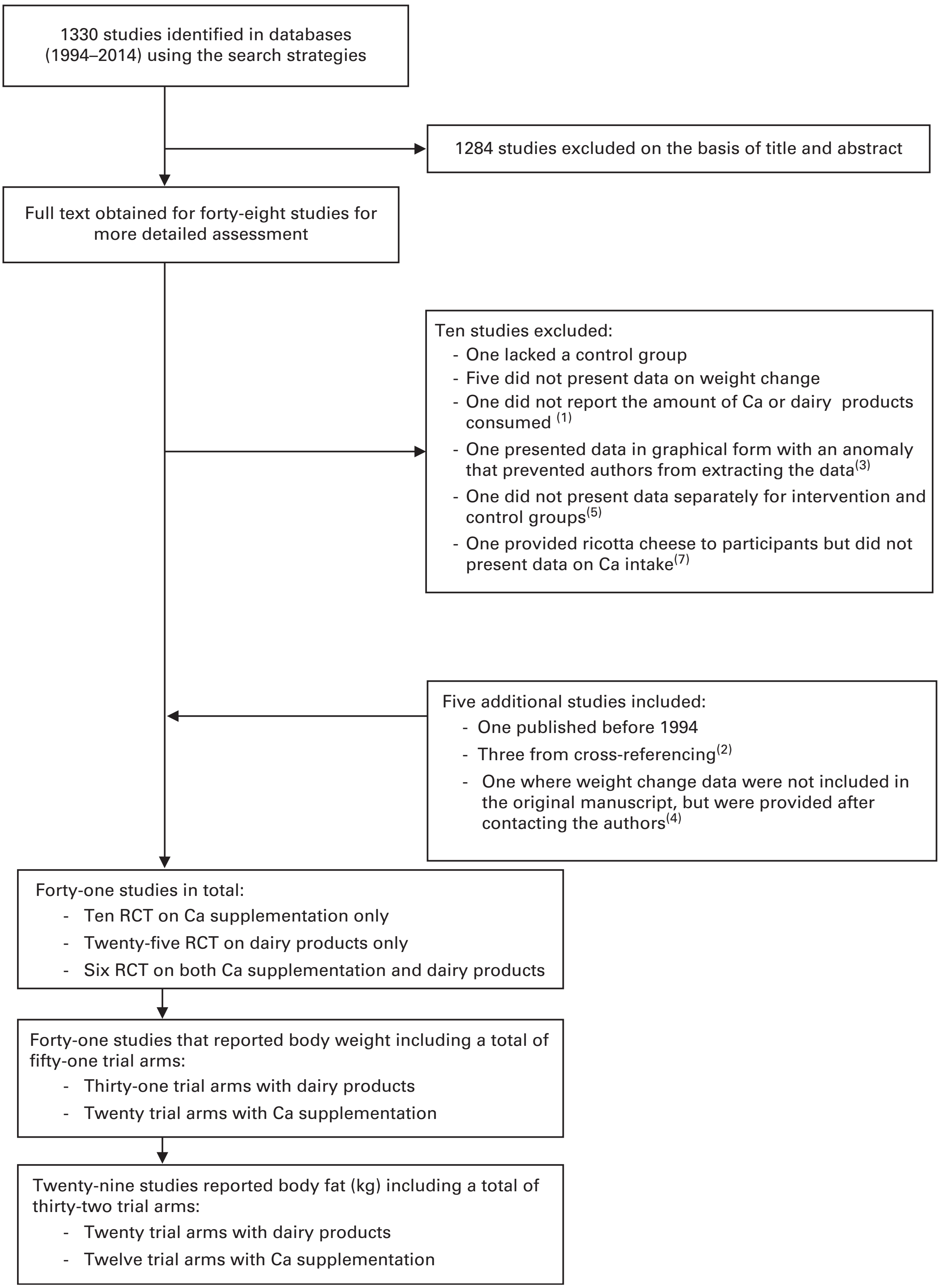

Fig. 1. Flow chart of process of study inclusion and exclusion.

Table 1. Study characteristics (intervention with calcium supplements)

Study	Country	Number of participants*	Sex, population characteristics	Age (years)	Ca dose (mg/d)	Study length	Energy restricted diet?	Main outcome
Jensen *et al.* (2001)[42]	Denmark	52 (24)	Female (obese, postmenopausal)	NA	1000†‡	6 months	Yes	Bone
Major *et al.* (2009)[48]§	Canada	63 (30)	Female (overweight, obese)	42	1000‖	15 weeks	Yes	Lipids, glucose, blood pressure
Shalileh *et al.* (2010)[56]¶	Iran	40 (20)	Mixed (overweight, obese)	37	1000‖	24 weeks	Yes	Body weight + body composition
Shapses *et al.* (2004)[4]¶	USA	22 (11)	Female (obese, postmenopausal)	56	1000**††	25 weeks	Yes	Bone
Smilowitz *et al.* (2011)[39]	USA	61 (16)	Mixed (overweight, obese)	25	900‖	12 weeks	Yes	Body composition + lipids
Wagner *et al.* (2007A)[41]	USA	58 (12)	Female (obese, overweight, premenopausal)	40	800**	12 weeks	Yes	Body weight + bone
Wagner *et al.* (2007B)[41]	USA	58 (16)	Female (obese, overweight, premenopausal)	42	800‡‡	12 weeks	Yes	Body weight + bone
Zemel *et al.* (2004)[37]¶	USA	41 (13)	Mixed (obese)	46	800‖	24 weeks	Yes	Body weight
Zemel *et al.* (2009)[40]¶	USA	106 (36)	Mixed (overweight, obese, BMI 25–34·9 kg/m^2, Ca intake < 800 mg/d)	25	900‖	12 weeks	Yes	Body composition
Zhu *et al.* (2013)[57]	China	43 (22)	Mixed (18–25 years, overweight or obese, Ca intake < 600 mg/d)	20	600‖	12 weeks	Yes	Body weight + body composition
Manios *et al.* (2009)[30]	Greece	101 (39)	Female (postmenopausal)	62	1200‖§§	12 months	No	Bone
Palacios *et al.* (2011)[38]¶	Puerto Rico	25 (9)	Mixed (obese)	35 (Ca) 39 (Placebo)	600‖	21 weeks	No	Body composition
Reid *et al.* (2005)[46]¶	New Zealand	1741 (732)	Female (postmenopausal, > 55 years)	74	1000**	30 months	No	Bone
Reid *et al.* (2010)[31]¶	New Zealand	215 (108)	Male (over 40 years)	56	600**	24 months	No	Bone, lipids, blood pressure
Reid *et al.* (2010)[31]¶	New Zealand	215 (108)	Male (over 40 years)	57	1200**	24 months	No	Bone, lipids, blood pressure
Rosenblum *et al.* (2012)[54]	USA	131 (66)	Mixed (overweight, obese)	40	350‡‡§§	16 weeks	No	Body weight + body composition
Shapses *et al.* (2004)[4]¶	USA	36 (17)	Female (obese, postmenopausal)	59	1000**††	25 weeks	No	Bone
Shapses *et al.* (2004)[4]¶	USA	42 (18)	Female (obese, premenopausal)	41	1000**††	25 weeks	No	Bone
Winters-Stone & Snow (2004)[47]¶	USA	23 (13)	Female (athletes)	25	1000‖	12 months	No	Bone
Yanovski *et al.* (2009)[18]¶	USA	340 (168)	Mixed	39	1500‖	24 months	No	Body weight

NA, not available.
* Numbers in parentheses indicate number in the intervention group.
† Calcium gluconate.
‡ Calcium lactobionate.
§ Reported body composition, method not stated.
‖ Calcium carbonate.
¶ Measured body composition via dual-energy X-ray absorptiometry.
** Calcium citrate.
†† Calcium citrate malate.
‡‡ Calcium phosphate.
§§ Calcium lactate gluconate.

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Table 2. Study characteristics (supplementation with dairy products)

Study	Country	Number of participants*	Sex, population characteristics	Age (years)†	Ca amount and dairy type	Study length	Energy-restricted diet?	Main outcome
Bowen *et al.* (2004)[58]	Australia	50 (25)	Mixed (obese)	48	2400 mg/d‡§‖	12 weeks	Yes	Bone
Frestedt *et al.* (2008)[59]¶	USA	59 (31)	Mixed (obese, BMI 30–42 kg/m^2)	43	482 mg/d**	12 weeks	Yes	Body weight + body composition
Gilbert *et al.* (2011)[60]¶	Canada	41 (13)	Female (overweight, obese)	42	1000 mg/d‡	6 months	Yes	Body weight + appetite
Harvey-Berino *et al.* (2005)[8]¶	USA	54 (25)	Mixed (fifty female, four male, overweight or obese)	45	3–4 portions, 1200–1400 mg/d††‡‡§§	12 months	Yes	Body weight
Jones *et al.* (2013)[61]	Canada	38 (20)	Mixed (overweight, obese, BMI 27–37 kg/m^2)	50–52	1400 mg/d‡§	12 weeks	Yes	Body weight + appetite
Josse *et al.* (2011)[62]	Canada	60 (30)	Female (overweight, obese)	19–45	1840 mg/d‖‖	16 weeks	Yes	Body composition
Rosado *et al.* (2011)[63]	Mexico	139 (46)	Female (obese)	34	1215 mg/d‡	16 weeks	Yes	Body weight
Smilowitz *et al.* (2011)[39]	USA	61 (16)	Mixed (overweight, obese)	25	3 portions, 1400 mg/d††‡‡§§	12 weeks	Yes	Body composition + lipids
Tanaka *et al.* (2014)[45]	Japan	102 (98)	Male (overweight, obese)	42	667 mg/d Ca 400 g/d Dairy††‡‡§§	24 weeks	Yes	Waist, blood pressure + lipids
Thomas *et al.* (2010)[64]¶	USA	29 (14)	Female (overweight)	36	> 1200 mg/d‡§‖	16 weeks	Yes	Body composition + bone
Thompson *et al.* (2005)[2]¶	USA	59 (30)	Mixed (obese)	41–42	4 servings/d (at least 2 of milk)††¶¶	48 weeks	Yes	Body weight
Torres *et al.* (2010)[65]	Brazil	50 (19)	Mixed (obese)	38–43	1230 mg/d***	16 weeks	Yes	Body composition + lipids
Torres *et al.* (2013)[66]	Brazil	35 (18)	Mixed (obese)	41–44	1246 mg/d***	16 weeks	Yes	Biomarkers of inflammation
Van Loan *et al.* (2011)[67]¶	USA	71 (35)	Mixed (overweight, obese)	32	1288 mg/d‡§†††	12 weeks	Yes	Body weight + body composition
Wagner *et al.* (2007)[41]	USA	58 (17)	Female (postmenopausal, overweight, obese)	42	800 mg/d‡	12 weeks	Yes	Bone + body weight
Witbracht *et al.* (2013)[44]¶	USA	51 (24)	Female (20–45 years, overweight and obese, BMI 28–37 kg/m^2)	31–33	≥ 711 ml/d milk††, ≥ 129 g/d cheese§§, ≥ 681 g/d yoghurt‡‡ or combination	12 weeks	Yes	Cortisol responsiveness
Zemel *et al.* (2004)[37]¶	USA	41 (14)	Mixed (obese)	46	3 servings/d, 1200–1300 mg/d††‡‡§§	24 weeks	Yes	Body weight
Zemel *et al.* (2009)[40]¶	USA	106 (32)	Mixed (overweight, obese, BMI 25–34·9 kg/m^2, Ca intake < 800 mg/d)	26	1400 mg/d††‡‡§§	12 weeks	Yes	Body composition
Zemel *et al.* (2005)[68]¶	USA	35 (18)	Mixed (obese)	39–42	3 servings/d§, (additional 600 mg/d)	12 weeks	Yes	Body weight + body composition
Angeles-Agdeppa (2010)[19]	Philippines	60 (30)	Female (postmenopausal)	56	2000 mg/d***	16 weeks	No	Body weight
Barr *et al.* (2000)[33]	USA	200 (98)	Mixed	65	3 servings/d (1200–1300 mg/d)‡	12 weeks	No	Body weight + blood pressure
Chee *et al.* (2003)[69]¶	Malaysia	173 (91)	Female (postmenopausal)	59	1200 mg/d***	24 months	No	Bone
Crichton *et al.* (2012)[70]¶	Australia	71 (32)	Mixed (overweight, obese)	NS (18–71)	4 portions, 1452 mg/d‡§‡‡‡	6 months	No	Waist circumference
Gunther *et al.* (2005)[29]¶	USA	155 (48)	Female (Ca intake < 800 mg/d)	20	1300–1400 mg/d‡§‖	12 weeks	No	Fat oxidation
Haub *et al.* (2005)[5]¶	USA	37 (20)	Female (postmenopausal)	60	2201 mg/d§§§	12 months	No	Body composition + body weight
Kukuljan *et al.* (2009)[71]	Australia	180 (44)	Males	62–60	1000 mg/d‡	12 months	No	Bone
Lau *et al.* (2001)[72]¶	China	185 (95)	Female (postmenopausal)	57	800 mg/d***	24 months	No	Bone
Manios *et al.* (2009)[30]	Greece	101 (26)	Female (postmenopausal)	62	1200 mg/d‡§	12 months	No	Bone
Palacios *et al.* (2011)[38]¶	Puerto Rico	25 (8)	Mixed (obese)	38	4 portions, 1200–1400 mg/d‡§‖	21 weeks	No	Body composition + lipids
Stancliffe *et al.* (2011)[43]¶	USA	40 (20)	Mixed (overweight, obese)	37	3 portions, < 1000 mg/d¶¶	12 weeks	No	Oxidative and inflammatory stress

Table 2. *Continued*

Study	Country	Number of participants*	Sex, population characteristics	Age (years)†	Ca amount and dairy type	Study length	Energy-restricted diet?	Main outcome
Wennersberg *et al.* (2009)[73]¶	Norway, Finland, Sweden	113 (56)	Mixed (overweight, BMI ≤38 kg/m^2)	57 (f) 51 (m)	3–5 portions/d, 1145 mg/d‡§||||||||||	6 months	No	Body composition

NS, not stated; f, female; m, male.
* Numbers in parentheses indicate number in the intervention group.
† A mean age range is provided for studies that presented mean age separately for each group (control and intervention).
‡ Milk low fat or skim.
§ Yoghurt low fat or skim.
|| Cheese low or reduced fat.
¶ Measured body composition via dual-energy X-ray absorptiometry.
** Prolibra with milk minerals and Ca.
†† Milk type not stated or no preference.
‡‡ Yoghurt type not stated or no preference.
§§ Cheese fat not stated or no preference.
|||| High protein, high dairy diet
¶¶ Dairy type not specified.
*** Milk powder low or no fat.
††† Cheese full fat.
‡‡‡ Low or reduced fat custard.
§§§ Ca fortified beverage.
|||||| Cream.

control)[30,31,33,37–40]; in two studies, four trial arms were included (one included two Ca supplement groups, one dairy group plus one control group and the other was divided into three supplement groups plus one control group)[4,41].

Study characteristics: calcium supplementation

Sixteen studies reported nineteen trial arms with Ca supplementation. Of the nineteen trial arms that used Ca supplements, sixteen used a placebo control (nine of these with energy restriction or weight loss diet), two used usual diet as the control and one used an energy-restricted diet without a Ca supplement.

Of the sixteen studies, five reported bone parameters as the main outcome, two reported body weight as the main outcome, two reported body composition, one reported lipids and the remaining six studies reported more than one main outcome including bone plus weight, bone plus lipids, weight plus body composition, body composition plus lipids and weight, composition and metabolic factors. Of the nineteen trial arms within the sixteen studies, nine incorporated energy restriction, thirteen included obese or overweight participants, ten were in women only, and five were in postmenopausal women. Ten studies were from North America, two were from New Zealand, two were from Europe, and there was one each from Iran and Puerto Rico. Mean study length was 9 months and ranged from 3 to 24 months. Mean age was 43 (SD 14) years and ranged from 20 to 74 years. One study[42] did not report age. The supplements provided a mean of 913 (SD 253) mg of Ca/d, range 350–1500 mg/d.

Study characteristics: dairy food supplementation

Of the thirty-one studies with dairy food supplementation, nineteen included energy-restricted diets, twenty-one included obese or overweight participants, twelve were in females only, and six were in postmenopausal women. Of the thirty-one studies (including thirty-one trial arms of dairy food supplementation), five studies reported bone parameters as the main outcome; five reported body weight as the main outcome; two reported body composition; five reported both body weight and body composition; three reported body composition plus lipids; two reported body weight plus appetite; one reported waist circumference, blood pressure and lipids; and one each of oxidative stress, fat oxidation, biomarkers of inflammation, body weight plus blood pressure, body weight plus bone parameters, body composition plus bone parameters, and waist circumference. One study that reported body weight as the main outcome used protein in milk as the treatment focus, not Ca.

Of the thirty-one trial arms that used dairy supplementation, seven used a usual diet control; nineteen used a low dairy, low Ca or placebo control; one used a moderate dairy control; and four used a special diet (lower in Ca) as the control. In all studies with energy restriction, this restriction was employed in both the intervention and control groups. Twenty were from North America, four were from Asia, three were from Australia, two were from Europe and two were from

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South America. Mean study length was 7 months with a range from 3 to 24 months. Mean age was 44 (SD 11·5) years and ranged from 20 to 70 years. Mean Ca provided by dairy foods was 1326 (SD 401) mg of Ca/d, range 482–2400 mg of Ca/d.

Twenty-one of the thirty-one studies (68 %) instructed participants to consume low-fat, reduced-fat or no-fat dairy foods and one study supplied a low-fat Ca-fortified beverage containing 7 % non-specified milk[5]. Seven[2,8,37,39,43–45] of the remaining nine studies did not specify dairy fat content, one[40] instructed participants to choose either low- or full-fat dairy foods, and the other[6] specified daily energy from fat at 30 % in both the dairy supplemented and control groups.

Meta-analysis

Calcium supplementation and body weight. The Ca supplement studies had a combined total of 2711 participants. Fig. 2(a) shows the association between Ca supplementation and body weight change. The pooled analysis showed that there was no difference in weight change between the intervention and control groups (−0·17, 95 % CI −0·70, 0·37 kg, P=0·54).

Of the Ca supplement studies, eight reported compliance rates. Of these, all reported high compliance of above 75 %[4,30,31,38,39,41,46,47]. Pooled analysis of these eight studies (n 1701) showed there was no difference in weight change between the Ca supplemented and control groups (−0·02, 95 % CI −0·31, 0·28k g).

Dairy food supplementation and body weight. The dairy food supplement studies had a combined total of 2091 study participants. Fig. 3(a) shows the association between Ca supplementation and change in body weight. The pooled analysis showed that there was no difference in mean weight change for the groups receiving dairy supplementation compared to the control groups (−0·06, 95 % CI −0·54, 0·43 kg).

Measurement of body composition. To assess if there was some beneficial effect of Ca or the inclusion of dairy on body composition, the trials that incorporated measurement of body composition were pooled and analysed (Figs. 2(b) and 3(b)). Ten Ca supplement studies (with twelve trial arms) and twenty-one dairy food supplement studies (with twenty-one trial arms) reported change in body fat (kg) or body fat at baseline and completion. Of these, thirty measured fat using dual-energy X-ray absorptiometry and one did not specify how body composition was measured[48].

Calcium supplementation and body composition. The ten Ca supplement studies with twelve trial arms had a combined total of 2350 participants. Fig. 2(c) shows the association between Ca supplementation and change in body fat (kg). Pooled analyses showed there was no difference in mean body fat change compared to the control groups (−0·19, 95 % CI −0·51, 0·13 kg, P=0·24).

Dairy food supplementation and body composition. Twenty-one dairy food supplement studies had a combined total of 1289 study participants. Fig. 3(c) shows the association between dairy food supplementation and change in body fat (kg). The pooled analysis showed that there was no difference in mean body fat change for the groups receiving dairy supplementation compared to the control groups (−0·36, 95 % CI −0·80, 0·09 kg, P=0·81).

Effect of calcium and dairy intervention combined with energy restriction on body weight. To assess if there was some beneficial effect of Ca or the inclusion of dairy products in assisting with weight loss, the trials that incorporated energy restriction or encouraged weight loss were pooled and analysed (Figs. 2(b) and 3(b)). The nine Ca supplement studies with energy restriction had a combined total of 350 study participants with a mean study length of 4 months. There was no difference in mean weight change compared to control groups (−0·34, 95 % CI −1·15, 0·46 kg).

Nineteen dairy food supplement trials with energy restriction had a combined total of 1010 participants. These are relatively short-term studies, with a mean study length of 4 months (range 3–12 months). Average dairy intake of Ca was 1318 mg/d, equivalent to approximately 3 servings of dairy/d. There was no difference in weight change between the intervention and control groups when combined with dietary energy restriction (−0·32, 95 % CI −0·93, 0·30 kg, P=0·31).

Effect of dairy food supplementation combined with energy restriction on body composition. The effect of dairy food supplementation on body fat when combined with energy restriction was analysed (Fig. 3(d)). Thirteen dairy supplement studies with a combined total of 564 participants (mean age 38 (SD 7·0) years) and a mean study length of 4 months were included in the analysis. Fat loss was significantly greater in the dairy supplemented group compared to the control, when combined with energy restriction (−0·96, 95 % CI −1·46, −0·46 kg, P <0·001).

Test for publication bias. There was no evidence for publication bias among the Ca supplementation (Egger's regression P=0·21) (Fig. 4(a)) or dairy supplement trials reporting body weight (Egger's regression P=0·07) (Fig. 4(b)).

For the trials reporting body composition, there was no statistical evidence of publication bias among the Ca supplement studies (Egger's regression P=0·40) or the dairy supplement studies (Egger's regression P=0·10) (online Supplementary Fig. S2 for funnel plots).

Discussion

To determine if increasing dietary Ca could reduce body weight or body fat, a meta-analysis of randomised controlled trials assessing whether Ca supplements or increased Ca from dairy foods resulted in weight or fat loss was undertaken. These analyses show that increased Ca provision in the form of dairy foods or Ca supplements does not increase weight or fat loss compared to control groups. This finding differs from Onakpoya *et al.*[20] who conducted a meta-analysis on seven Ca supplementation studies and found that Ca supplementation resulted in a small but significant reduction in body weight and body fat. However, this study included only seven studies that had body weight as the primary outcome, whereas the present study included all studies (n 16) that provided increased Ca in the form of Ca supplementation that also measured body weight or body composition at two time points.

The limitations of these reviews include the narrow selection of included studies (half of available published studies)[21]; and inclusion of studies with intervention periods of very short duration (<12 weeks duration)[22].

Contrary to two previous meta-analyses[21,22], the current analysis found that consumption of about 3 servings of reduced fat dairy foods on an energy-restricted diet did not result in a greater mean weight change compared to the

(a)

Study or subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight (%)	Mean difference	95 % CI
Shapses *et al.* (2004C)[4]	−6·7	5·5	18	−4·3	3·5	24	2·9	−2·40	−5·30, 0·50
Zemel *et al.* (2004)[37]	−8·58	5·31	11	−6·6	8·16	10	0·8	−1·98	−7·93, 3·97
Winters-Stone & Snow (2004)[47]	−0·9	4·2	13	0·7	6·4	10	1·3	−1·60	−6·18, 2·98
Shalileh *et al.* (2010)[56]	−2·65	0·13	20	−1·55	0·51	20	18·0	−1·10	−1·33, −0·87
Major *et al.* (2009)[48]	−4	7·8	30	−3	10·2	33	1·3	−1·00	−5·46, 3·46
Zhu *et al.* (2013)[57]	−4·1	1·8	22	−3·5	1·9	21	10·3	−0·60	−1·71, 0·51
Smilowitz *et al.* (2011)[39]	−3·4	10·5	16	−3·2	10·3	23	0·6	−0·20	−6·85, 6·45
Rosenblum *et al.* (2012)[54]	−2·5	3·3	66	−2·4	3·2	65	10·3	−0·10	−1·21,1·01
Reid *et al.* (2005)[46]	−0·368	3·57	732	−0·369	3·64	739	17·1	0·00	−0·37, 0·37
Yanovski *et al.* (2009)[18]	0·54	8·23	168	0·52	8·84	167	5·9	0·02	−1·81,1·85
Shapses *et al.* (2004A)[4]	−7	4·6	17	−7·3	5·3	19	2·4	0·30	−2·93, 3·53
Reid *et al.* (2010)[31]	0·23	3	108	−0·07	2·88	107	13·3	0·30	−0·49, 1·09
Wagner *et al.* (2007B)[41]	−5·4	5·2	16	−5·8	2·88	13	2·7	0·40	−2·59, 3·39
Palacios *et al.* (2011)[38]	−0·2	15	9	−0·6	11·4	8	0·2	0·40	−12·19, 12·99
Jensen *et al.* (2001)[42]	−5·4	11·9	25	−6·2	12·8	27	0·6	0·80	−5·91, 7·51
Zemel *et al.* (2009)[40]	−2·27	3·88	19	−3·15	3·16	26	4·7	0·88	−1·25, 3·01
Shapses *et al.* (2004B)[4]	−6·7	2·6	11	−7·6	5·7	11	1·9	0·90	−2·80, 4·60
Manios *et al.* (2009A)[30]	0·9	11·9	26	−0·7	8·6	36	0·9	1·60	−3·77, 6·97
Wagner *et al.* (2007A)[41]	−4·1	2·42	12	−5·8	2·88	13	4·9	1·70	−0·38, 3·78
Total (95 % CI)			1339			1372	100·0	−0·17	−0·70, 0·37

Heterogeneity: $\tau^2=0{\cdot}40$; $\chi^2=44{\cdot}71$, df=18 ($P=0{\cdot}0005$); $I^2=60$ %
Test for overall effect: $Z=0{\cdot}62$ ($P=0{\cdot}54$)

(b)

Study or subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight (%)	Mean difference	95 % CI
Zemel *et al.* (2004)[37]	−8·58	5·31	11	−6·6	8·16	10	1·8	−1·98	−7·93, 3·97
Shalileh *et al.* (2010)[56]	−2·65	0·13	20	−1·55	0·51	20	42·2	−1·10	−1·33, −0·87
Major *et al.* (2009)[48]	−4	7·8	30	−3	10·2	33	3·0	−1·00	−5·46, 3·46
Zhu *et al.* (2013)[57]	−4·1	1·8	22	−3·5	1·9	21	23·9	−0·60	−1·71, 0·51
Smilowitz *et al.* (2011)[39]	−3·4	10·5	16	−3·2	10·3	23	1·4	−0·20	−6·85, 6·45
Jensen *et al.* (2001)[42]	−5·4	11·9	25	−6·2	12·8	27	1·4	0·80	−5·91, 7·51
Zemel *et al.* (2009)[40]	−2·27	3·88	19	−3·15	3·16	26	10·8	0·88	−1·25, 3·01
Shapses *et al.* (2004B)[4]	−6·7	2·6	11	−7·6	5·7	11	4·3	0·90	−2·80, 4·60
Wagner *et al.* (2007A)[41]	−4·1	2·42	12	−5·8	2·88	13	11·2	1·70	−0·38, 3·78
Total (95 % CI)			166			184	100·0	−0·34	−1·15, 0·46

Heterogeneity: $\tau^2=0{\cdot}39$; $\chi^2=12{\cdot}13$, df=8 ($P=0{\cdot}15$); $I^2=34$ %
Test for overall effect: $Z=0{\cdot}83$ ($P=0{\cdot}41$)

(c)

Study or subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight (%)	Mean difference	95 % CI
Shapses *et al.* (2004C)[4]	−5·2	5	18	−3	3·5	24	1·4	−2·20	−4·90, 0·50
Zhu *et al.* (2013)[57]	−2·8	1·3	22	−1·8	1·3	21	12·9	−1·00	−1·78, −0·22
Zemel *et al.* (2004)[37]	−5·61	5·31	11	−4·81	3·86	10	0·6	−0·80	−4·75, 3·15
Major *et al.* (2009)[48]	−3·3	5·4	30	−2·7	7·3	33	1·0	−0·60	−3·75, 2·55
Reid *et al.* (2010)[31]	0·58	2·11	108	1·05	2·71	107	16·9	−0·47	−1·12, 0·18
Shapses *et al.* (2004A)[4]	−6·1	4·2	17	−6·1	4·7	19	1·2	0·00	−2·91, 2·91
Shapses *et al.* (2004B)[4]	−4·8	2·1	11	−4·8	3·9	11	1·4	0·00	−2·62, 2·62
Reid *et al.* (2005)[46]	0·163	0·146	732	0·113	0·145	739	57·5	0·05	0·04, 0·06
Shalileh *et al.* (2010)[56]	−0·49	12·01	20	−0·69	5·4	20	0·3	0·20	−5·57, 5·97
Yanovski *et al.* (2009)[18]	0·4	6·68	168	0·01	7·62	167	4·0	0·39	−1·14,1·92
Zemel *et al.* (2009)[40]	−2·23	3·72	19	−2·69	2·7	26	2·5	0·46	−1·51, 2·43
Palacios *et al.* (2011)[38]	0·24	5·9	9	−0·43	7·2	8	0·3	0·67	−5·63, 6·97
Total (95 % CI)			1165			1185	100·0	−0·19	−0·51, 0·13

Heterogeneity: $\tau^2=0{\cdot}05$; $\chi^2=12{\cdot}87$, df=11 ($P=0{\cdot}30$); $I^2=15$ %
Test for overall effect: $Z=1{\cdot}18$ ($P=0{\cdot}24$)

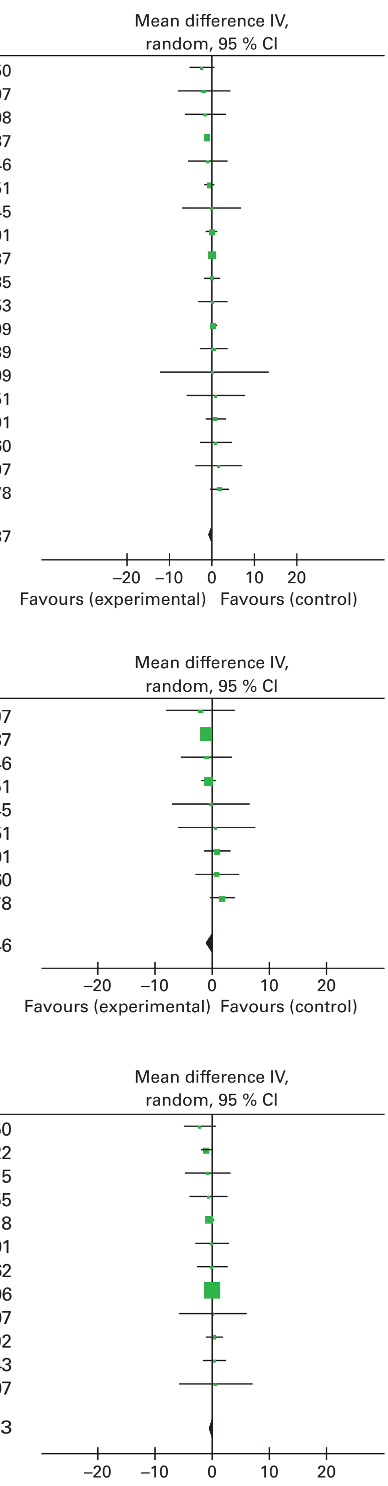

Fig. 2. (a) Association between calcium supplementation and change in body weight and (b) separated for trials with energy-restricted diets and (c) calculating body fat. (A colour version of this figure can be found online at http://www.journals.cambridge.org/bjn).

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control. However, the current meta-analysis had broader selection criteria, which resulted in additional studies being included[21], and strict inclusion criteria (studies with >12 weeks duration) resulting in a more robust analysis[22]. Although cross-sectional studies have found consistent associations between high dairy consumption and lower body weight and BMI[6,9–11], these are subject to confounding, and the overall impact on body weight with increased dairy consumption from longitudinal studies have been inconsistent.

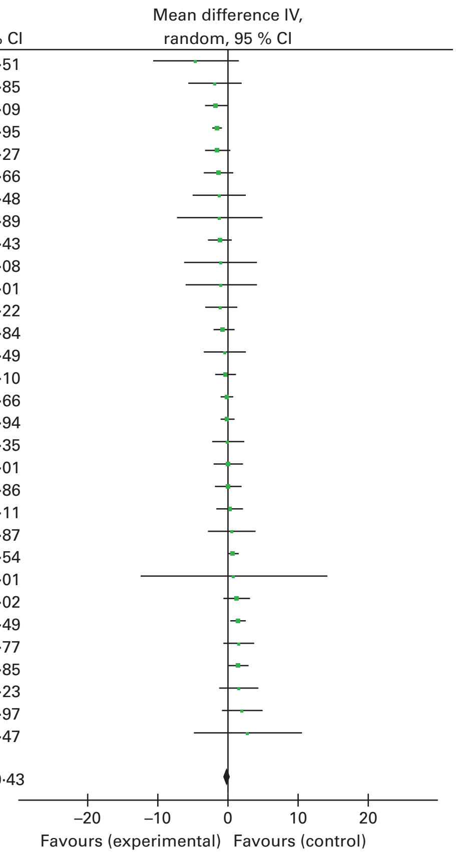
In support of the two previous analyses, the current analysis did find that consumption of about 3 servings of reduced-fat dairy foods, but not Ca supplements, on an energy-restricted diet resulted in a greater mean fat loss of 920 g over

(a)

Study or subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight (%)	Mean difference	95 % CI
Zemel *et al.* (2004)[37]	−11·07	5·41	11	−6·6	8·16	10	0·6	−4·47	−10·45,1·51
Thompson *et al.* (2005)[2]	−11·8	6·1	22	−10	6·8	26	1·4	−1·80	−5·45, 1·85
Zemel *et al.* (2005)[68]	−6·63	2·6	18	−4·99	2	16	4·3	−1·64	−3·19, −0·09
Stancliffe *et al.* (2011)[43]	−0·4	0·4	20	1·1	1·2	20	7·0	−1·50	−2·05, −0·95
Zemel *et al.* (2009)[40]	−4·61	3·02	23	−3·15	3·16	26	3·9	−1·46	−3·19, 0·27
Torres *et al.* (2010)[65]	−5·1	3·49	19	−3·8	2·68	20	3·4	−1·30	−3·26, 0·66
Harvey-Berino *et al.* (2005)[8]	−10·8	5·9	23	−9·6	6·5	21	1·4	−1·20	−4·88, 2·48
Smilowitz *et al.* (2011)[39]	−4·3	10·2	22	−3·2	10·3	23	0·6	−1·10	−7·09, 4·89
Jones *et al.* (2013)[61]	−3·3	2·68	20	−2·2	2·12	18	4·3	−1·10	−2·63, 0·43
Witbracht *et al.* (2013)[44]	−6·5	8·9	24	−5·5	9·6	27	0·8	−1·00	−6·08, 4·08
Angeles-Agdeppa *et al.* (2010)[19]	0·8	8·7	30	1·7	10·6	30	0·9	−0·90	−5·81, 4·01
Torres *et al.* (2013)[66]	−5·3	3·82	18	−4·4	2·47	17	3·1	−0·90	−3·02, 1·22
Frestedt *et al.* (2008)[59]	−3·82	3·06	31	−3·24	2·49	28	4·6	−0·58	−2·00, 0·84
Rosado *et al.* (2011)[63]	−3·6	6·8	43	−3·2	6·7	41	2·1	−0·40	−3·29, 2·49
Van Loan *et al.* (2011)[67]	−6·3	2·9	35	−6	3·1	36	4·7	−0·30	−1 ·70, 1·10
Chee *et al.* (2003)[69]	0·04	2·58	91	0·16	2·63	82	6·4	−0·12	−0·90, 0·66
Wennersberg *et al.* (2009)[73]	−0·1	2·5	57	−0·1	2·6	56	5·9	0·00	−0·94, 0·94
Gunther *et al.* (2005)[29]	0·9	2·5	9	0·8	2·5	10	2·9	0·10	−2·15, 2·35
Haub *et al.* (2005)[5]	0·1	3	17	0	2·9	20	3·5	0·10	−1 ·81, 2·01
Josse *et al.* (2011)[62]	−4·26	3·37	30	−4·36	3·57	30	3·8	0·10	−1·66,1·86
Bowen *et al.* (2004)[58]	−9	3	25	−9·3	3·5	25	3·7	0·30	−1·51, 2·11
Barr *et al.* (2000)[33]	1·2	12·1	98	0·6	11·5	102	1·7	0·60	−2·67, 3·87
Lau *et al.* (2001)[72]	0·52	2·63	95	−0·26	2·66	90	6·4	0·78	0·02, 1·54
Palacios *et al.* (2011)[38]	0·3	15·1	8	−0·6	11·4	8	0·1	0·90	−12·21, 14·01
Kukuljan *et al.* (2009)[71]	1·3	4·33	45	0	3·95	44	3·9	1·30	−0·42, 3·02
Tanaka *et al.* (2014)[45]	−1·1	3·3	102	−2·6	3·8	98	5·8	1·50	0·51, 2·49
Wagner *et al.* (2007C)[41]	−4·2	3·3	17	−5·8	2·77	13	3·0	1·60	−0·57, 3·77
Crichton *et al.* (2012)[70]	1·8	2·4	36	0·2	3	36	5·1	1·60	0·35, 2·85
Thomas *et al.* (2010)[64]	−1·1	2·5	14	−2·7	4·5	15	2·4	1·60	−1·03, 4·23
Manios *et al.* (2009)[30]	1·4	2·02	39	−0·7	8·57	36	2·1	2·10	−0·77, 4·97
Gilbert *et al.* (2011)[60]	−2·9	11·8	13	−5·8	7·1	12	0·4	2·90	−4·67, 10·47
Total (95 % CI)			1055			1036	100·0	−0·06	−0·54, 0·43

Heterogeneity: τ^2=0·80; χ^2=70·10, df=30 (P<0·0001); I^2=57 %

Test for overall effect: Z=0·23 (P=0·81)

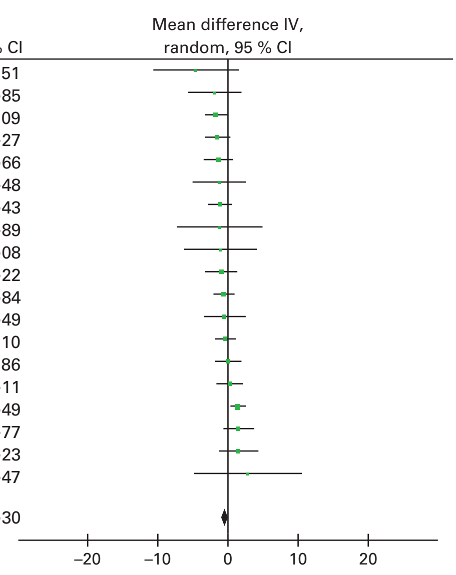


(b)

Study or subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight (%)	Mean difference	95 % CI
Zemel *et al.* (2004)[37]	−11·07	5·41	11	−6·6	8·16	10	1·0	−4·47	−10·45,1·51
Thompson *et al.* (2005)[2]	−11·8	6·1	22	−10	6·8	26	2·4	−1·80	−5·45, 1·85
Zemel *et al.* (2005)[68]	−6·63	2·6	18	−4·99	2	16	8·0	−1·64	−3·19, −0·09
Zemel *et al.* (2009)[40]	−4·61	3·02	23	−3·15	3·16	26	7·1	−1·46	−3·19, 0·27
Torres *et al.* (2010)[65]	−5·1	3·49	19	−3·8	2·68	20	6·2	−1·30	−3·26, 0·66
Harvey-Berino *et al.* (2005)[8]	−10·8	5·9	23	−9·6	6·5	21	2·4	−1·20	−4·88, 2·48
Jones *et al.* (2013)[61]	−3·3	2·68	20	−2·2	2·12	18	8·2	−1·10	−2·63, 0·43
Smilowitz *et al.* (2011)[39]	−4·3	10·2	22	−3·2	10·3	23	1·0	−1·10	−7·09, 4·89
Witbracht *et al.* (2013)[44]	−6·5	8·9	24	−5·5	9·6	27	1·4	−1·00	−6·08, 4·08
Torres *et al.* (2013)[66]	−5·3	3·82	18	−4·4	2·47	17	5·6	−0·90	−3·02, 1·22
Frestedt *et al.* (2008)[59]	−3·82	3·06	31	−3·24	2·49	28	8·8	−0·58	−2·00, 0·84
Rosado *et al.* (2011)[63]	−3·6	6·8	43	−3·2	6·7	41	3·6	−0·40	−3·29, 2·49
Van Loan *et al.* (2011)[67]	−6·3	2·9	35	−6	3·1	36	8·9	−0·30	−1·70,1·10
Josse *et al.* (2011)[62]	−4·26	3·37	30	−4·36	3·57	30	7·0	0·10	−1·66,1·86
Bowen *et al.* (2004)[58]	−9	3	25	−9·3	3·5	25	6·8	0·30	−1·51, 2·11
Tanaka *et al.* (2014)[45]	−1·1	3·3	102	−2·6	3·8	98	11·5	1·50	0·51, 2·49
Wagner *et al.* (2007C)[41]	−4·2	3·3	17	−5·8	2·77	13	5·4	1·60	−0·57, 3·77
Thomas *et al.* (2010)[64]	−1·1	2·5	14	−2·7	4·5	15	4·1	1·60	−1·03, 4·23
Gilbert *et al.* (2011)[60]	−2·9	11·8	13	−5·8	7·1	12	0·6	2·90	−4·67, 10·47
Total (95 % CI)			510			502	100·0	−0·32	−0·93, 0·30

Heterogeneity: τ^2=0·60; χ^2=28·61, df=18 (P=0·05); I^2=37 %

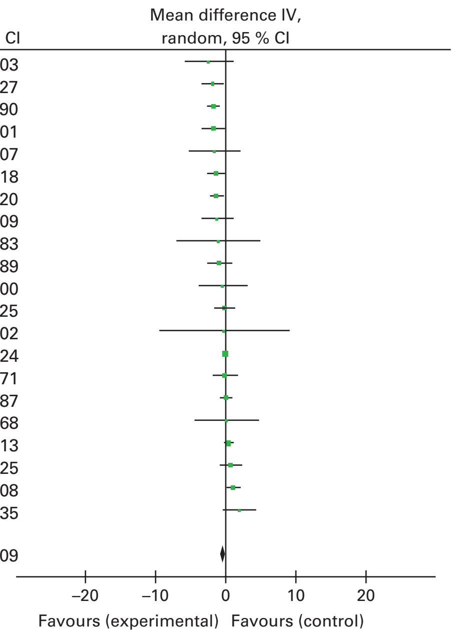
Test for overall effect: Z=1·01 (P=0·31)



(c)

Study or subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight (%)	Mean difference	95 % CI
Zemel *et al.* (2004)[37]	−7·16	4·05	11	−4·81	3·86	10	1·5	−2·35	−5·73, 1·03
Zemel *et al.* (2009)[40]	−4·43	2·54	23	−2·69	2·7	26	5·1	−1·74	−3·21, −0·27
Stancliffe *et al.* (2011)[43]	−1·3	0·9	20	0·4	1·6	20	8·5	−1·70	−2·50, −0·90
Zemel *et al.* (2005)[68]	−4·43	1·99	18	−2·75	2·9	16	4·3	−1·68	−3·37, 0·01
Thompson *et al.* (2005)[2]	−9	6	22	−7·5	6·6	26	1·4	−1·50	−5·07, 2·07
Josse *et al.* (2011)[62]	−4·84	2·73	30	−3·64	2·74	30	5·5	−1·20	−2·58, 0·18
Frestedt *et al.* (2008)[59]	−2·81	2·12	31	−1·62	1·75	28	7·5	−1·19	−2·18, −0·20
Harvey-Berino *et al.* (2005)[8]	−10·1	3·6	23	−9	3·8	21	3·0	−1·10	−3·29, 1·09
Gilbert *et al.* (2011)[60]	−6	8·8	13	−5	5·9	12	0·5	−1·00	−6·83, 4·83
Torres *et al.* (2013)[66]	−4·5	2·97	18	−3·7	2·06	17	4·4	−0·80	−2·49, 0·89
Witbracht *et al.* (2013)[44]	−5	5·2	24	−4·7	6·8	27	1·6	−0·30	−3·60, 3·00
Van Loan *et al.* (2011)[67]	−5·2	2·8	35	−5·1	3	36	5·6	−0·10	−1·45,1·25
Palacios *et al.* (2011)[38]	−0·52	11	8	−0·43	7·2	8	0·2	−0·09	−9·20, 9·02
Chee *et al.* (2003)[69]	−0·04	1·14	91	−0·04	0·18	82	11·5	0·00	−0·24, 0·24
Haub *et al.* (2005)[5]	1·3	2·6	17	1·3	2·7	20	4·3	0·00	−1·71, 1·71
Wennersberg *et al.* (2009)[73]	−0·3	2·2	57	−0·4	2	56	8·7	0·10	−0·67, 0·87
Jones *et al.* (2013)[61]	−1·6	6·6	20	−1·8	7·4	18	0·9	0·20	−4·28, 4·68
Lau *et al.* (2001)[72]	0·42	1·95	95	−0·14	1·99	90	9·9	0·56	−0·01, 1·13
Kukuljan *et al.* (2009)[71]	0·7	3·66	45	−0·1	3·29	44	5·2	0·80	−0·65, 2·25
Crichton *et al.* (2012)[70]	1·3	2·4	36	0·2	1·8	36	7·5	1·10	0·12, 2·08
Thomas *et al.* (2010)[64]	−1·8	2·1	14	−3·8	4·1	15	2·7	2·00	−0·35, 4·35
Total (95 % CI)			651			638	100·0	−0·36	−0·80, 0·09

Heterogeneity: τ^2=0·43; χ^2=50·76, df=20 (P=0·0002); I^2=61 %
Test for overall effect: Z=1·58 (P=0·11)



(d)

Study or subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight (%)	Mean difference	95 % CI
Zemel *et al.* (2004)[37]	−7·16	4·05	11	−4·81	3·86	10	2·2	−2·35	−5·73, 1·03
Zemel *et al.* (2009)[40]	−4·43	2·54	23	−2·69	2·7	26	11·6	−1·74	−3·21, −0·27
Zemel *et al.* (2005)[68]	−4·43	1·99	18	−2·75	2·9	16	8·8	−1·68	−3·37, 0·01
Thompson *et al.* (2005)[2]	−9	6	22	−7·5	6·6	26	2·0	−1·50	−5·07, 2·07
Josse *et al.* (2011)[62]	−4·84	2·73	30	−3·64	2·74	30	13·1	−1·20	−2·58, 0·18
Frestedt *et al.* (2008)[59]	−2·81	2·12	31	−1·62	1·75	28	25·7	−1·19	−2·18, −0·20
Harvey-Berino *et al.* (2005)[8]	−10·1	3·6	23	−9	3·8	21	5·2	−1·10	−3·29, 1·09
Gilbert *et al.* (2011)[60]	−6	8·8	13	−5	5·9	12	0·7	−1·00	−6·83, 4·83
Torres *et al.* (2013)[66]	−4·5	2·97	18	−3·7	2·06	17	8·8	−0·80	−2·49, 0·89
Witbracht *et al.* (2013)[44]	−5	5·2	24	−4·7	6·8	27	2·3	−0·30	−3·60, 3·00
Van Loan *et al.* (2011)[67]	−5·2	2·8	35	−5·1	3	36	13·8	−0·10	−1·45,1·25
Jones *et al.* (2013)[61]	−1·6	6·6	20	−1·8	7·4	18	1·3	0·20	−4·28, 4·68
Thomas *et al.* (2010)[64]	−1·8	2·1	14	−3·8	4·1	15	4·5	2·00	−0·35, 4·35
Total (95 % CI)			282			282	100·0	−0·96	−1·46, −0·46

Heterogeneity: τ^2=0·00; χ^2=10·96, df=12 (P=0·53); I^2=0 %
Test for overall effect: Z=3·74 (P=0·0002)

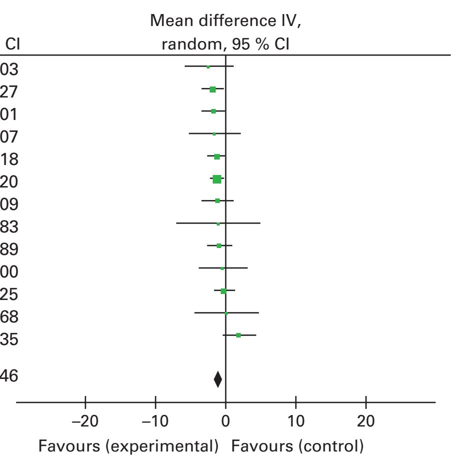


Fig. 3. (a) Association between dairy food supplementation and change in body weight and (b) separated for trials with energy-restricted diets and (c) those that measured body composition and (d) trials with energy-restricted diets that also measured body composition. (A colour version of this figure can be found online at http://www.journals.cambridge.org/bjn).

4 months in twenty-one studies. These results indicate the importance of separating out trials that are designed to facilitate fat loss from those where energy intake is not restricted.

It appears that consuming 3 servings of reduced-fat dairy products each day may assist in appetite control, although this is probably not related to amount of dietary Ca and is more likely to be related to other components present in dairy products. Dairy products are high in protein and increasing dietary protein intake increases satiety and can lead to weight loss[49–51]. In addition to protein, there is evidence that especially casein proteins present in dairy products have a long-term satiating effect in humans[52]. In addition, the increase in dietary protein resulting from increased consumption of dairy products may be assisting in maintaining lean mass when combined with resistance training[6]. The specific mechanisms whereby consumption of dairy product within the context of an energy-restricted diet may assist with fat loss are not known. Importantly though, the findings indicate only a small difference in fat change over a short time frame and whether this is likely to continue over the long term remains to be determined. For most weight loss interventions, the greatest effects are usually seen early in the intervention period. However, the two studies[2,8] in this category that were conducted for longer than 6 months did not show a significant difference in fat change between the intervention and control groups, suggesting that the effect of increased consumption of dairy foods on fat loss may attenuate over time.

While this meta-analysis did not find an indication that Ca supplement had an effect on body weight or fat mass, there is some evidence that consuming additional supplementary Ca can have a small effect in increasing fecal fat excretion, leading to a small net energy loss; however, this effect has

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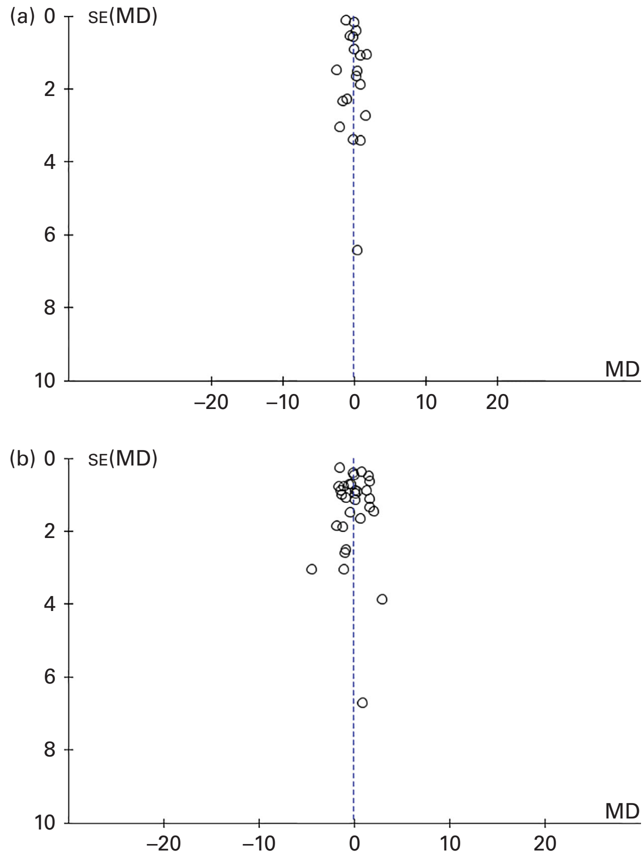

Fig. 4. Publication bias was assessed using a funnel plot depicting the mean difference (MD) between the intervention and control groups (treatment effect) against the standard error (SE) of the mean difference. (a) Funnel plot of all randomised controlled trials (RCT) of calcium supplementation reporting body weight, Egger's regression, $P=0·21$ indicates no publication bias. (b) Funnel plot of all RCT of dairy food supplementation reporting body weight, Egger's regression, $P=0·07$ indicates no publication bias. Mid-vertical line represents the zero mean difference or zero effect size. (A colour version of this figure can be found online at http://www.journals.cambridge.org/bjn).

been predicted to be less than 1 kg/year provided no other counter-regulatory effects are present[13]. It has been suggested that Ca supplementation may aid weight loss if usual Ca intake is low[53]. However, there were too few studies within the current meta-analysis that combined low usual Ca intakes with energy restriction for a separate analysis. It has also been suggested that Ca combined with vitamin D may reduce visceral body fat[54]; however, this could not be explored in the present study as there were no studies that provided vitamin D and also assessed for visceral fat.

Strengths and limitations

Only studies with intervention periods of 12 weeks or more that also resulted in an increased intake of at least 300 mg of Ca/d were included. Nine of sixteen supplementation studies and twenty-one of thirty-one trials of dairy supplementation had body weight or body composition as a key outcome, with the remaining studies having bone or stress as the key outcome with change in body weight as a secondary outcome, and it could be argued that these studies were not designed to evaluate weight change. However, weight change is easy to measure and is reproducible, which is necessary for the interpretation of studies evaluating bone outcome; therefore, the fact that it was not the primary measure should not influence these results. Another potential limitation may be the heterogeneity of the studies included; however, this was attenuated by using a random effects model. The included studies were predominantly Caucasian populations and these results may be different in other populations, particularly those consuming very low levels of dietary Ca. It is possible that other confounding factors may influence a relationship between dairy and body composition or body weight that were unable to be taken into consideration, such as physical activity and other dietary factors.

In summary, a robust meta-analysis method with large subject numbers showed that there was no evidence that increased Ca provision in the form of supplements or dairy foods reduces body weight or body fat. There was some evidence that consumption of approximately 3 servings/d of reduced fat dairy foods (approximately 1300 mg/d Ca) in the presence of energy restriction resulted in a small, but significant greater loss of body fat mass over a short period of 4 months. This indicates that low fat dairy foods can be included as part of a healthy weight loss diet without having negative effect on body weight or body composition in the short term[55].

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S0007114515001518

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