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# Self-Reported Changes in Dietary Calcium and Energy Intake Predict Weight Regain following a Weight Loss Diet in Obese Women ,[1,2]

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## Abstract

This study examined relationships between changes in dietary calcium intake, energy intake, and body weight following a weight loss diet. One hundred three overweight or obese women lost weight over 22 wk. Dietary calcium and energy intake were assessed using the Block 98 FFQ (Block) and 5-d food records (FR) at intervention end and 6- and 18-mo follow-up. Pearson correlations were used to relate changes in dietary calcium to energy intake. We used regression analyses to examine relationships between changes in dietary calcium, energy intake, and weight regain. Changes in dietary calcium and energy intake were correlated ($r = 0.32$; $P = 0.033$), but neither variable alone predicted weight regain. From 6- to 18-mo follow-up, greater dietary calcium intake inversely predicted weight regain when controlling for changes in energy intake ($P = 0.048$ Block and 0.025 FR), whereas higher energy intake positively predicted weight regain when controlling for changes in dietary calcium intake ($P = 0.009$ Block and 0.049 FR) (combined $R^2 = 0.153$ Block and 0.178 FR). Dietary calcium may oppose weight regain, reducing the effect of greater energy intake. Our results encourage future research on the potential relationship between dietary calcium and weight loss maintenance and suggest that controlling for dietary calcium may increase the ability of energy intake to predict weight change.

## Introduction

An area of particular interest in current obesity research is the potential association between calcium intake and body weight. Inverse associations have been reported between calcium intake and body weight in both retrospective (1–4) and prospective (5) analyses. Some studies have shown that calcium is inversely associated with body fat percentage (3,5,6). Additional studies have found an inverse relationship between calcium intake and the OR of being overweight or obese (4,7), as well as between calcium intake and abdominal adipose tissue (3). Two recent randomized control trials revealed nonsignificant trends in the direction of a positive effect of calcium intake on weight loss (8,9).

In contrast, some literature suggests that calcium may not affect changes in body weight or fat mass (10–13). Jensen et al. (10) randomized obese women on a weight loss diet to calcium-supplemented (1 g/d) or no intervention groups for 3 mo but found no differences in body weight or fat loss. Macdonald et al. (11) examined calcium intake in an observational study and found no relationship with changes in body weight over 5–7 y. Wosje and Kalkwarf (12) found calcium supplementation (1 g/d) did not promote weight or fat loss over 6 mo in postpartum women. In addition, Bowen et al. (13) compared effects of high dairy (2400 mg

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calcium/d) and moderate dairy (500 mg calcium/d) isoenergetic diets and found no associations between calcium and body weight or composition.

Calcium review articles are similarly split in their conclusions. Parikh and Yanovski (14) stated " …most of the available cross-sectional, longitudinal, observational, and small controlled trials in humans and the available animal studies support the conclusion that dietary calcium may play a role in body weight regulation and lend credence to the hypothesis that increasing dietary calcium or dairy intake may diminish future weight gain" (p. 286). Conversely, Barr (15) states: "…the data available from randomized trials of dairy product or calcium supplementation provide little support for an effect in reducing body weight or fat mass" (p. 245S). Barr (15) also states: "The interpretation of these [null] findings is complicated by the inability to accurately determine the extent of dietary compensation for the increment in energy intake provided by the added dairy products" (p. 245S). This statement acknowledges the potential import of controlling for energy intake when examining the relationship between calcium and weight change. As such, this study used dietary calcium intake to predict weight loss maintenance both with and without controlling for energy intake.

Despite the attention received, any effect of calcium on weight loss itself may hold limited utility in combating the obesity epidemic. Up to 50% of lost weight is typically regained within 1 y and ~90% is typically regained within 5 y (16). To our knowledge, this study is the first to report weight loss maintenance data in relation to calcium. In addition, the fundamental tenet of energy balance posits that, with relatively constant energy expenditure, increased energy intake should predict increased body weight (17). Many studies, however, fail to show this relationship (17–19), suggesting that additional variables need to be controlled for when predicting changes in body weight from energy intake. Changes in dietary calcium have been positively related to changes in energy intake (20,21), suggesting that dietary calcium and energy intake increase concurrently, but may have opposing effects on body weight. This study also examined whether changes in dietary calcium and energy intake were positively associated yet correlated with weight maintenance (regain) in opposing directions.

The primary aims of this study were to examine the predictive value of changes in dietary calcium and energy intake on changes in body weight for 18 mo following a weight loss diet. Specific hypotheses were as follows: *1*) Changes in dietary calcium and energy intake would be positively related; *2*) without controlling for changes in energy intake, changes in dietary calcium intake would not predict weight regain; *3*) controlling for changes in energy intake, changes in dietary calcium intake would inversely predict weight regain; *4*) without controlling for changes in dietary calcium intake, changes in energy intake would not predict weight regain; and *5*) controlling for changes in dietary calcium intake, changes in energy intake would positively predict weight regain.

## Materials and Methods

### Participants

A total of 103 women were recruited in the Philadelphia area (Table 1); 61% were Caucasian, 36% African American, and 3% Asian. Participants were screened for any mental or physical conditions and medications that may have affected body weight. Attrition rates were 22.3% at intervention end, 31.1% at 6-mo follow-up, and 39.8% at 18- mo follow-up. Completers did not differ from drop-outs in any measured variable at intake and attrition did not vary by condition. This study was approved by the Drexel University Institutional Review Board.

## Design

In a previously completed study, participants were prescribed a 5023 kJ/d meal replacement diet for an 8-wk weight loss period. This consisted of 4 daily servings of liquid Optifast (Novartis Nutrition), a frozen entree (from a list), and 112 g salad with 15 mL nonfat dressing. Each serving of Optifast provided 1005 kJ, 16 g protein, 37 g carbohydrate, and 6 g fat. Each frozen entree provided ~1047 kJ, 25 g protein, 25 g carbohydrate, and 7 g fat. Participants were given no instructions regarding vitamin or mineral supplements but were asked not to make changes to established vitamin or supplement regimens during the study unless directed by a physician. For the following 14 wk, participants returned to conventional foods and were randomly assigned to the following 3 different weight loss maintenance conditions: *1*) Cognitive behavioral therapy for weight loss maintenance; *2*) cognitive behavioral therapy plus enhanced food monitoring accuracy training; and *3*) cognitive behavioral therapy and enhanced food monitoring plus reduced energy density eating training. However, groups did not differ in weight change across any assessment points (Table 2). Therefore, analyses in this study included data for all participants who had completed the necessary measures at each assessment point. Few participants completed all measures at all assessment points, resulting in a different *n* for most analyses. The *n* for individual assessments are reported. All intervention ended at 22 wk. Dietary calcium and energy intake were assessed using the Block 98 FFQ (Block) and 5-d food records (FR) at intake, intervention end, 6-mo follow-up, and 18-mo follow-up.

## Statistical methods

Means, SD, and change scores were calculated for dietary calcium intake, energy intake, and body weight (Table 3). Supplemental calcium intake was 347 ± 521 at intake, 360 ± 570 post-treatment, 314 ± 481 at 6-mo follow-up, and 364 ± 482 mg at 18-mo follow-up. Pearson correlations were used to relate changes in dietary calcium to changes in energy intake. Paired samples *t* tests were used to examine significant changes in variables across assessment periods. We performed regression analyses to examine the relationship between changes in dietary calcium intake and weight regain, as well as the relationship between changes in energy intake and weight regain, individually. Regression analyses were then repeated, with changes in dietary calcium and energy intake entered simultaneously to examine the relationship between each predictor variable and weight regain while holding the other variable constant. Amount of weight lost on the diet and age were entered as controls. In post hoc analyses, changes in dietary fat, protein, carbohydrate, fiber, and supplemental calcium intake were used to test the specificity of dietary calcium results. We measured dietary fat, protein, carbohydrate, and fiber intake using the Block and FR and supplemental calcium intake using only the Block. Regression analyses were used to examine each individual variable's ability to predict weight regain independent of energy intake, as well as the ability of changes in energy intake to predict weight regain, controlling for each individual predictor variable. We accomplished this by regressing changes in dietary fat, protein, carbohydrate, fiber, and supplemental calcium on changes in body weight. Each variable was entered individually, both with and without changes in energy intake. All analyses were conducted using SPSS version 14. Results were considered significant at $P < 0.05$.

## Anthropometric measurements

Weight was measured with participants in light street clothing, without shoes, using a Tanita BWB-800P digital scale accurate to 0.1 kg. Height was measured using a standardized stadiometer.

## Dietary intake

The 110-item Block (22) was designed to assess nutrient intake levels, specific food groups, and vitamin and supplement intake. The Block has been validated for nutrient intake (23) and individual differences in intake (24). In FR, participants recorded time, description (brand and ingredients), portion size/amount, and preparation information for all eating and drinking each day for *5* consecutive days. Participants were given detailed instructions on measuring portion sizes. Data obtained from FR were entered into Nutritionist V software (First Databank) by graduate students supervised by a doctoral-level nutritionist. Recipe and manufacturer's nutrient information were manually entered for food items not available in the software database.

## Results

### Relationship between changes in dietary calcium and energy intake

Changes in dietary calcium intake were positively correlated with changes in energy intake across all measurement points (Table 4).

### Relationship between changes in dietary calcium intake, energy intake, and weight regain

**Postintervention to 18-mo follow-up—**Neither changes in dietary calcium nor energy intake alone predicted weight regain according to Block and FR data. Controlling for changes in energy intake, changes in dietary calcium intake inversely predicted weight regain according to Block ($P = 0.033$) but not FR data. Controlling for changes in dietary calcium intake, changes in energy intake positively predicted weight regain according to Block ($P = 0.047$) but not FR data (Table 5). Using Block data, the unstandardized coefficient (not shown) for (1 mg) change in dietary calcium intake was −0.016. Therefore, holding energy intake constant, a 100-mg increase in dietary calcium intake was associated with 1.6 kg less weight regain over this period.

**Postintervention to 6-mo follow-up—**Neither changes in dietary calcium nor energy intake, entered singly or simultaneously, predicted weight regain according to Block and FR data (not shown).

**6-Mo follow-up to 18-mo follow-up—**Neither changes in dietary calcium nor energy intake alone predicted weight regain according to Block and FR data. Controlling for changes in energy intake, changes in dietary calcium intake inversely predicted weight regain according to Block ($P = 0.048$) and FR ($P = 0.025$) data. Controlling for changes in dietary calcium intake, changes in energy intake positively predicted weight regain according to Block ($P = 0.009$) and FR ($P = 0.049$) data (Table 6). According to Block and FR data, the unstandardized coefficient (not shown) for (1 mg) change in dietary calcium intake was −0.012. Therefore, holding energy intake constant, a 100-mg increase in dietary calcium intake was associated with 1.2 kg less weight regain over this period.

### Post hoc analyses examining the predictive value of changes in supplemental calcium, macronutrient, fiber, and energy intake

Changes in dietary fat, protein, carbohydrate, fiber, and supplemental calcium intake all failed to predict weight regain across all measurement points. Results were consistent both with and without controlling for changes in energy intake according to Block and FR data (not shown). In addition, while controlling for each individual predictor variable (dietary fat, protein, carbohydrate, fiber, and supplemental calcium), changes in energy intake failed to predict weight regain across all measurement points according to Block and FR data (not shown).

## Discussion

Results support the hypothesis that, without controlling for energy intake, no relationship can be found between changes in dietary calcium intake and body weight following a weight loss diet, likely due to the high correlation between changes in dietary calcium and energy intake

(Table 3). The 6- to 18-mo follow-up data lend some support for the hypothesis that dietary calcium may be inversely related to weight regain following a weight loss diet; however, this effect was not seen from postintervention to 6 mo. Although not supporting or refuting the postulated antiobesity effects of calcium (25), the 6- to 18-mo data may be consistent with both aforementioned reviews of the calcium literature. That is, a failure to adequately control for energy intake may mask an existing relationship between calcium and body weight, yielding nonsignificant results (15). Controlling for energy intake may reveal a relationship between changes in dietary calcium and body weight during and following a weight loss diet (14). However, great care must be taken in interpreting correlational data and prospective research is needed to substantiate the proposed relationship between dietary calcium and weight loss maintenance.

Controlling for changes in energy intake, dietary calcium was the only measured nutrient that predicted weight regain. Consistent with previous literature (26,27), dietary calcium in our sample was derived mainly from dairy sources. The failure of changes in supplemental calcium to predict changes in body weight is also consistent with literature reporting that dairy sources of calcium may be more strongly related to changes in body weight than supplemental calcium carbonate (7,28). Further prospective research is needed to elucidate this issue as well.

The failure of changes in energy intake to predict weight regain was also consistent with predictions and indicates that related variables may be suppressing the effect of changes in energy intake on changes in body weight. This study tested the contention that dietary calcium intake would account for enough variance in weight regain for energy intake to predict weight regain when dietary calcium intake is held constant. Analyses revealed a positive relationship between changes in energy and dietary calcium intake, suggesting that when more kilojoules are ingested, more dietary calcium is as well. Further analyses revealed a positive relationship between greater energy intake and body weight from 6- to 18-mo follow-up controlling for changes in dietary calcium. Combined with results suggesting an inverse relationship between changes in dietary calcium and body weight, these findings suggest that dietary calcium and energy intake may increase concurrently but have opposing effects on body weight.

Results also demonstrated that changes in energy intake failed to predict weight regain when individually controlling for changes in dietary fat, protein, carbohydrate, fiber, and supplemental calcium intake. Thus, changes in energy intake predicted weight regain only when controlling for changes in dietary calcium intake. The inability to find a significant relationship between changes in energy intake and body weight has often been attributed to food intake underreporting and other difficulties in the assessment of energy intake (19,29). However, there is little data supporting this contention. Although only speculations can be made based on correlational data, results in this study suggest that controlling for changes in dietary calcium intake may increase the ability of energy intake to predict weight change. Energy intake assessment (17,30) and weight loss maintenance (16) continue to be areas of particular difficulty in obesity research. We hope this study will inspire further work aimed toward improving the assessment of energy intake and preventing weight regain following weight loss diets in overweight and obese individuals.

### Limitations

The central limitation of this study is its retrospective design. As Davies et al. (2) point out, it cannot be determined whether the effect noted in this study was due to calcium per se or to other nutrients with which calcium is a correlate. In addition, energy expenditure was not measured. Differences in Block and FR data attested to difficulties associated with assessing energy intake and it is not uncommon for these 2 measures to yield different results (31,32). It remains unclear why significance was not found in postintervention to 6-mo follow-up analyses. Weight regain from postintervention to 6-mo follow-up (1.9 ± 3.4 kg) ranged from

−12.75 to 7.98 kg vs. −11.52 to 13.24 kg from 6- to 18-mo follow-up (3.3 ± 3.8 kg). It is possible that the smaller range in, and amount of, weight regain from postintervention to 6-mo follow-up provided insufficient power to detect an effect. However, power analyses revealed suboptimal power coefficients across all measurement points, ranging from 0.58 to 0.76 calculated for a medium effect size. With previous literature reporting relatively small- to medium-effect sizes (2,4,25), higher correlation coefficients may have been found with a larger sample.

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**TABLE 1**

Baseline characteristics of 103 overweight or obese women[1]

| | |
|---|---|
| Age, *y* | 43.87 ± 10.49 |
| Height, *cm* | 163.86 ± 6.61 |
| Weight, *kg* | 85.53 ± 9.54 |
| BMI, *kg/m²* | 31.85 ± 2.61 |

[1]Values are means ± SD.

## TABLE 2

Weight change of overweight or obese women across weight loss and follow-up periods[1]

| Assessment period | kg |
|---|---|
| Pre to post[2] | −9.66 ± 4.11* |
| Post to 6-mo follow-up[3] | 1.89 ± 3.37* |
| Post to 18-mo follow-up[4] | 4.99 ± 5.15* |
| 6- to 18-mo follow-up[5] | 3.35 ± 3.85* |

[1] Values are means ± SD.

[2] Wk 0–22, $n = 79$.

[3] Wk 22–48, $n = 70$.

[4] Wk 22–100, $n = 61$.

[5] Wk 48–100, $n = 61$.

* Significant change, $P < 0.001$ (paired sample $t$ test).

**TABLE 3**

Dietary calcium and energy intake of overweight or obese women derived from the Block and FR records across weight loss and follow-up periods[1,2]

| Assessment period | Block | | FR | |
|---|---|---|---|---|
| | Calcium | Energy | Calcium | Energy |
| | *mg/d* | *kJ/d* | *mg/d* | *kJ/d* |
| Preintervention | 832 ± 441 | 8895 ± 5241 | 714 ± 297 | 8682 ± 2478 |
| Postintervention | 735 ± 309 | 6551 ± 3102 | 708 ± 275 | 6677 ± 1909 |
| 6-mo follow-up | 703 ± 336 | 6455 ± 3102 | 729 ± 225 | 7309 ± 1486 |
| 18-mo follow-up | 831 ± 369 | 6995 ± 2964 | 717 ± 275 | 7112 ± 1691 |

[1]Values are means ± SD.

[2]*n* range from 45 to 103 for each individual mean.

**TABLE 4**

Pearson correlations between changes in dietary calcium and energy intake in overweight or obese women across weight loss and follow-up periods.

| Assessment period | Block | FR |
|---|---|---|
| | *r* | |
| Pre to post | 0.702** | 0.396** |
| Post to 6-mo follow-up | 0.744** | 0.342** |
| Post to 18-mo follow-up | 0.739** | 0.319* |
| 6- to 18-mo follow-up | 0.670** | 0.529** |

*$P < 0.05$;

**$P < 0.01$.

## TABLE 5

Predictive value of changes in dietary calcium and energy intake on weight regain in overweight or obese women from intervention end to 18-mo follow-up.

| | Block[1] | | | FR[2] | | |
|---|---|---|---|---|---|---|
| | **β[3]** | ***P*** | ***R*²** | **β[3]** | ***P*** | ***R*²** |
| Entered singly | | | | | | |
| Dietary Ca intake | −0.145 | 0.308 | 0.043 | −0.068 | 0.663 | 0.021 |
| Energy intake | 0.128 | 0.572 | 0.023 | 0.178 | 0.275 | 0.044 |
| Entered simultaneously | | | 0.117 | | | 0.059 |
| Dietary Ca intake | −0.442 | 0.033* | | −0.127 | 0.426 | |
| Energy intake | 0.412 | 0.047* | | 0.237 | 0.143 | |

[1] $n = 51$.

[2] $n = 43$.

[3] Standardized coefficients.

* $P < 0.05$.

**TABLE 6**

Predictive value of change in dietary calcium and energy intake on weight regain in overweight or obese women from 6- to 18-mo follow-up

| | Block[1] | | | FR[2] | | |
|---|---|---|---|---|---|---|
| | β[3] | *P* | $R^2$ | β[3] | *P* | $R^2$ |
| Entered singly | | | | | | |
| Dietary Ca intake | −0.034 | 0.820 | 0.013 | −0.217 | 0.152 | 0.102 |
| Energy intake | 0.205 | 0.115 | 0.046 | 0.136 | 0.356 | 0.078 |
| Entered simultaneously | | | 0.153 | | | 0.178 |
| Dietary Ca intake | −0.380 | 0.048* | | −0.388 | 0.025* | |
| Energy intake | 0.511 | 0.009** | | 0.325 | 0.049* | |

[1] *n* = 48.

[2] *n* = 47.

[3] Standardized coefficients.

* $P < 0.05$;

** $P < 0.01$.