Symposium: Dairy Product Components and Weight Regulation

Calcium Intake and Reduction in Weight or Fat Mass[1]

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ABSTRACT Obesity is a growing epidemic with subsequent health consequences leading not only to reduced quality of life but also to increased medical costs. Growing evidence supports a relationship between increased calcium intakes and reductions in body weight specific to fat mass. Since the first observations in rats >10 y ago, several recently published clinical studies support this relationship as well. The impact of calcium intake on weight loss or prevention of weight gain has been demonstrated in a wide age range of Caucasian and African-Americans of both genders. This review focuses on the results of clinical trials that have investigated the impact of calcium and dairy products on prevention of weight gain, weight loss or development of the insulin resistance syndrome. The implications of these results are that calcium may play a substantial contributing role in reducing the incidence of obesity and prevalence of the insulin resistance syndrome. J. Nutr. 133: 249S–251S, 2003.

KEY WORDS: • *calcium* • *weight* • *fat mass* • *review* • *dairy*

The incidence of obesity has rapidly increased in the last 20 y and has become a national and global epidemic. It is a risk factor for chronic diseases such as heart disease, cancer, stroke and diabetes and weight loss is known to reduce the risk for some of these diseases. Although much effort has been devoted to studying the effects of macronutrients on weight control, the role of micronutrients has not been as well studied. Although energy balance is the most critical factor in weight regulation, recent studies suggest that calcium metabolism and perhaps other components of dairy products may contribute to shifting the energy balance and thus play a role in weight regulation. This review discusses the impact of calcium intake on body composition measures presented in clinical studies.

Although the focus of this review is on the impact of calcium in clinical trials, our interest in the area was piqued by two animal studies published >10 y ago (1,2). In 1988 Metz et al. (1) demonstrated a reduction in body fat mass in two strains of hypertensive rats' higher calcium intakes (in conjunction with a higher sodium intake). In addition, in 1989, an abstract by Bursey et al. (2) reported that increasing calcium in the diet from 0.1 to 2.0% resulted in a reduced weight gain in both lean and fatty Zucker rats. However, until recently this suggested relationship between calcium intake and body fat remained unexplored. After the presentation of two abstracts (3,4) at the same national meeting in 1999, substantial data have emerged to support this interesting and unexpected relationship between calcium intake and body fat mass.

The original studies in rats from the 1980s prompted our laboratory to take advantage of the data generated previously in a randomized study investigating the impact of a 2-y exercise intervention on bone mass in young women (5), to explore the relationship of calcium intake on changes in body composition (6). In the parent study, healthy normal weight 18–31 y old women were randomized into an exercise or nonexercise group after baseline testing. Three-day diet records were collected at baseline and 6-mo intervals, and averaged over the 2-y period of the study. Total body bone mineral content was assessed by dual X-ray absorptiometry, allowing an analysis of body composition changes as well. The results of 54 women who completed the 2-y trial were used. Calcium intakes were low (781 ± 212 mg/d), compared to the dietary reference intakes (1000 mg/d for most of this group), and the primary source of dietary calcium was from dairy intake (67%). When dietary calcium was expressed as a nutrient density (calcium/energy, g/kcal), it negatively predicted changes in body weight and body fat, but not lean mass. Dairy calcium predicted the changes as well as did nondairy calcium; however, the range of nondairy calcium intakes was low and may not have been sufficient to demonstrate a relationship.

To further explore why calcium intake predicted the changes only when corrected for calorie intakes, women were categorized into groups either above or below the mean caloric intake of the cohort (1876 kcal/d). Calcium intake did not predict changes in weight or fat mass in the group with calorie intakes above the mean, whereas calories positively predicted these changes; thus the higher the calories, the greater the increase in body fat. On the other hand, calcium, but not calories, negatively predicted changes in weight and fat mass

[1] Presented as part of the symposium "Dairy Product Components and Weight Regulation" given at the 2002 Experimental Biology meeting on April 21, 2002, New Orleans, LA. The symposium was sponsored in part by Dairy Management Inc. and General Mills, Inc. The proceedings are published as a supplement to *The Journal of Nutrition.* Guest editors for the symposium were Dorothy Teegarden, Department of Foods and Nutrition, Purdue University, West Lafayette, IN, and Michael B. Zemel, Departments of Nutrition and Medicine, The University of Tennessee, Knoxville, TN.

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in women with calorie intakes below the mean. Between 10 and 13% of the variability in weight and fat mass changes were accounted for by the calcium or dairy calcium intakes. The biological impact can be demonstrated by use of the resulting regression equation to estimate potential changes. In women with calorie intakes of <1876 calories/d, calcium intakes of 1000 mg/d predicted a body fat loss of ~2.6 kg over 2 y compared to a gain of ~1.8 kg at calcium intakes of 500 mg/d. These changes are substantial in normal weight young women and thus have important implications for the prevention of obesity.

Clearly, if dairy products are added to a diet without compensation for energy intake, one is likely to gain weight. This is shown in the study by Barr et al. (7), in which 204 men and women, aged 55–85 y, were randomized to either a control group or a dairy intervention group. The dairy intervention group was advised to increase skim or 1% milk intake from <1.5 servings to three servings/d. Although their overall nutrient intakes improved substantially, the dairy intervention group also gained 0.6 kg in the 12-wk trial, significantly more than did the control group. However, this gain was less than would be predicted by the increase in dairy products, suggesting that either the subjects altered their diets to compensate for the additional calories, or potentially that calcium or dairy shifted the energy balance to partially compensate for the additional calories.

Subsequently, other studies have been reanalyzed that, similar to our study, were not originally designed to study body fat mass. The results of these studies have supported the potential impact of calcium intake on body fat across a wide age range in both men and women. For example, dietary intakes of 53 children from the age of 24 to 60 mo were studied, followed by assessment of body fat mass at 70 mo (8). The higher the dietary intake of calcium, the lower the body fat mass at 70 mo. Davies et al. (9) reanalyzed five clinical trials that included ages ranging from the third to the eighth decade, to assess the impact of dietary calcium/protein intake on body weight or body mass index (BMI). These analyses included two cross-sectional, two longitudinal and one randomized, controlled trial totaling 780 women. In every case, the calcium/protein ratio negatively predicted either BMI or change in weight. Zemel et al. (10) used the NHANES III survey to further assess the impact of calcium on body fat. The analysis of women showed that the odds ratio of being in the highest body fat quartile was significantly reduced to 0.16 if they were in the highest calcium intake quartile. These results support the negative impact of calcium intake on body fat and its application to a variety of age groups.

This relationship has been noted in both men and women. One of the first observations of a potential relationship between calcium intake and body fat was noted in men > 10 y ago, similar to the rat studies described above. In this study, obese African-American men (n = 11) were randomized into a 1-y calcium intervention by adding yogurt to their diet to bring their calcium intakes to ~1000 mg/d (10). At the end of the intervention, the men on the yogurt diet had significantly lower body fat compared to those men on the basal diet containing a calcium intake of ~500 mg/d. However, these results remained unpublished until recently. The analysis by Zemel et al. (10) that made use of the NHANES III data demonstrated a similar relationship in men as was noted in women; that is, the odds ratio of being in the highest body fat quartile was significantly reduced if the men were in the highest calcium intake quartile. These results demonstrate that increased calcium intakes were associated with reduced body fat in men who were participating in both a large epidemiological study and a small intervention trial.

In addition to the study in African-American men noted above, a similar relationship between calcium intake and body fat was observed in African-American women (11). In this cross-sectional study, the higher the calcium/kcal ratio, the lower the BMI (R^2 = 0.47) in premenopausal lactose-tolerant women (n = 26). Thus, the associative relationship of calcium and body weight is also apparent in African-Americans.

The growing interest in this field is evidenced by the rapid increase in recent related abstracts or publications, each adding support for the relationship. The Quebec Family Study categorized both men (n = 235) and women (n = 235) aged 20–65 y by their calcium intakes into low (<600 mg/d), medium (600–1000 mg/d) or high (>1000 mg/d) (12). The women in the low calcium intake category were significantly higher than the other two groups in weight, percentage of body fat, fat mass, BMI, waist circumference and total abdominal adipose tissue. Another recent abstract described the results of a double-blind, placebo-controlled 3-y dietary calcium intervention study in young women (n = 52). Results showed that those women in the calcium supplement (1500 mg/d) group had a reduced body fat increase over the intervention period compared to that of placebo controls, further supporting the relationship between calcium and body weight (13). Again, this study was originally designed to assess the impact of calcium intake on bone mass in young women.

The impact of calcium may be particularly beneficial during weight loss, as evidenced by the results presented elsewhere in this symposium (14). However, dairy products, the predominant source of calcium in the U.S. diet, are commonly avoided in weight loss diets. Further evidence for this trend, and the potential importance in reducing this trend, are suggested by another recent abstract describing 181 overweight women aged 24–45 y who were enrolled in a 6-mo behavioral weight loss study (15). Their mean intake of calcium dropped from 833 to 681 mg/d during the weight loss trial. However, being in the highest quartile of calcium intake significantly predicted the change in body weight (R^2 = 0.12). These results as well as those of Zemel (14) suggest that calcium, and perhaps dairy products, should not be removed from weight loss diets, but instead may enhance the effects of the diet.

Finally, recent results generated from the Coronary Artery Risk Development in Young Adults (CARDIA) Study suggest an intriguing and exciting negative relationship between calcium intake or dairy consumption and obesity and insulin resistance syndrome (IRS) in young adults (16). In this prospective study, 3157 black and white adults aged 18 to 30 y were followed for 10 y. Dairy product intake was negatively associated with the cumulative incidence of IRS, including development of obesity, abnormal glucose homeostasis, elevated blood pressure and dyslipidemia, in overweight, but not in leaner participants. Neither lifestyle factors, race nor gender influenced the results. The investigators estimated that each additional serving of dairy products was associated with 21% lower odds of IRS. These interesting results provide support for an impact of dairy consumption, which may or may not be attributed to the calcium content, on reducing the incidence of important risk factors for chronic diseases.

In conclusion, the current and rapidly growing body of evidence is substantial and supports the relationship of dietary calcium intake to reductions in weight and body fat mass. However, it is important to confirm these observations in studies specifically designed to address this issue and in larger trials. It is also important to further understand the underlying mechanism(s) for this effect, and to determine whether the impact is greater in certain subgroups or while the energy balance is shifting. These results may have a substantial impact of increased calcium intake on reducing the incidence of obesity, as described in the analysis elsewhere in this symposium (17). Finally, studies to confirm the impact of dairy products on the development of IRS, suggested by the recently published study by Pereira et al. (16) are necessary. Although energy balance is the most important factor, if these results are confirmed, increasing the low dairy product and calcium intakes in the United States may greatly contribute to reducing the growing epidemic of obesity and IRS.

LITERATURE CITED

1. Metz, J. A., Karanja, N., Torok, J. & McCarron, D. A. (1988) Modification of total body fat in spontaneously hypertensive rats and Wistar-Kyoto rats by dietary calcium and sodium. Am. J. Hypertens. 1: 58–60.

2. Bursey, R. G., Sharkey, T. & Miller, G. D. (1989) High calcium intake lowers weight in lean and fatty Zucker rats. FASEB J. 3137: A265 (abs.).

3. Teegarden, D., Lin, Y.-C., Weaver, C. M., Lyle, R. M. & McCabe, G. P. (1999) Calcium intake relates to change in body weight in young women. FASEB J. 13: A873 (abs.).

4. Zemel, M. B., Shi, H., Zemel, P. C. & DiRienzo, D. (1999) Calcium and calcium-rich diary products reduce body fat. FASEB J. 12: LB211 (abs.).

5. Weaver, C. M., Teegarden, D., Lyle, R. M., McCabe, G. P., McCabe, L. D., Proulx, W. R., Kern, M., Sedlock, D., Anderson, D. D., Hillberry, B. M., Peacock, M. & Johnston, C. C. (2001) Impact of exercise on bone status in young women and contraindication of oral contraceptive use. Med. Sci. Sports Exerc. 33: 873–880.

6. Lin, Y.-C., Lyle, R. M., McCabe, L. D., McCabe, G. P., Weaver, C. M. & Teegarden, D. (2000) Calcium intake effects on two year changes in body composition in young women. J. Am. Coll. Nutr. 19: 754–760.

7. Barr, S. I., McCarron, D. A., Heaney, R. P., Dawson-Hughes, B., Berga, S. L., Stern, J. S. & Oparil, S. (2000) Effects of increased consumption of fluid milk on energy and nutrient intake, body weight, and cardiovascular risk factors in healthy older adults. J. Am. Diet. Assoc. 100: 810–817.

8. Carruth, B. R. & Skinner, J. D. (2001) The role of dietary calcium and other nutrients in moderating body fat in preschool children. Int. J. Obes. 25: 559–566.

9. Davies, K. M., Heaney, R. P., Recker, R. R., Lappe, J. M., Barger-Lux, M. J., Rafferty, K. & Hinders, S. (2000) Calcium intake and body weight. J. Clin. Endocrinol. Metab. 85: 4635–4638.

10. Zemel, M. B., Shi, H., Greer, B., DiRienzo, D. & Zemel, P. C. (2000) Regulation of adiposity by dietary calcium. FASEB J. 14: 1132–1138.

11. Buchowski, M. S., Semenya, J. & Johnson, A. O. (2002) Dietary calcium intake in lactose maldigesting intolerant and tolerant African-American women. J. Am. Coll. Nutr. 21: 47–54.

12. Jacqmain, M., Doucet, E., Despres, J.-P., Bouchard, C. & Tremblay, A. (2001) Calcium intake and body composition in adults. Obes. Res. 9: PF104 (abs.).

13. Barger-Lux, M. J., Davies, K. M., Heaney, R. P., Chin, B. K. & Rafferty, K. (2001) Calcium supplementation may attenuate accumulation of fat in young women. J. Bone Miner. Res. 16: S219.

14. Zemel, M. B. (2003) Mechanisms of dairy modulation of adiposity. J. Nutr. 133: 252S–256S.

15. Gentile, C., Gold, B. C. & Harvey-Berino, J. (2002) Calcium intake in overweight and obese women may not be high enough to facilitate weight loss. Obes. Res. 9: 615.

16. Pereira, M. A., Jacobs, D. R., Van Horn, L., Slattery, M. L., Kartashov, A. I. & Ludwig, D. S. (2002) Dairy consumption, obesity, and the insulin resistance syndrome in young adults. The CARDIA Study. J. Am. Med. Assoc. 287: 2081–2089.

17. Heaney, R. P. (2003) Normalizing calcium intake: projected population effects for body weight. J. Nutr. 133: 268S–270S.