Introduction: Obesity, Weight Loss, and Calcium

Obesity and overweight are serious health problems in the U.S., with an estimated 65% of adults either obese or overweight as of 2002 (1), and among children and adolescents the prevalence of overweight has nearly tripled over the past two decades to 16 % (1). Obesity and overweight are linked to higher levels of morbidity and mortality. Obese individuals have a 50 to 100% increased risk of premature death, and nearly 400,000 deaths were caused by poor diet and physical inactivity in the year 2000, making it the second most common cause of preventable death in the U.S (2, 3). Overweight and obesity have been shown to increase the risk for developing diseases including: type 2 diabetes, heart disease, some forms of cancer, and hypertension (4). Fortunately, even modest weight loss and body fat reduction are important factors in reducing morbidity and mortality (2). In light of the obesity epidemic and personal weight preferences, people in the United States are now using various foods, diets, supplements, vitamins, and techniques in their efforts to lose weight.

In April 2004 the National Dairy Council (NDC), citing new scientific research, claimed that eating 3-4 servings of dairy a day as part of a reduced calorie diet helps people to burn fat and lose weight (5, 13). Websites for dairy products such as yogurt and milk, citing the same research, have also suggested that adding 3-4 servings of low fat dairy to a reduced calorie diet will help people to lose more weight and body fat than on a low calcium diet or by taking calcium supplements (6,7, 13). Several observational studies have suggested a possible relationship between dairy/dietary calcium and weight loss or body fat reduction (10-12). However, randomized studies have mixed results as to whether dairy product or calcium supplementation significantly correlates with decreased weight or body fat when compared to controls (13-16).

Recent laboratory studies have described potential cellular mechanisms for calcium and its role in lipid metabolism. Studies of intracellular calcium and adipocytes propose that an increased dietary intake of calcium downregulates parathyroid hormone and $1,25(OH)_2$ vitamin D (calcitriol) (8). The reduction in calcitriol increases calcium uptake into adipocytes. This subsequently inhibits fatty acid synthesis, stimulates lipolysis and upregulates expression of uncoupling protein 2 (UCP2) in adipose tissue, which mediates fatty acid transport and oxidation, and therefore enables a reduction in adiposity (9).

Observational and Epidemiologic Studies

In light of this proposed mechanism, the findings in recent observational studies lend credence to the suggestion of a link between calcium and weight loss. Davies et al analyzed data from five clinical studies of calcium intake and osteoporosis, and found a significant negative correlation between calcium intake and body weight (as BMI) (10). Differences in the calcium: protein intake ratio indicate that calcium intake accounts for approximately 3% of the variance in body weight, with a 1000-mg calcium intake difference related to an 8-kg difference in mean body weight. In a two-year interventional study of non-obese women aged 18 to 31 years, total calcium/kilocalories predicted negative changes in body weight ($R2 = 0.19$) and body fat ($R2 = 0.27$) independent of exercise (11). Further, there was a relationship of calcium and energy intake in predicting

changes in body weight, where at lower energy intakes, calcium intake predicted changes in body weight. Subjects with increased calcium intake, corrected by total energy intake gained less weight and body fat over two years. Carruth and Skinner reported an inverse relationship between calcium/dairy product intake and total body fat, in a longitudinal study examining preschool children's food consumption (ages 24-60 months, n = 53) in relation to body composition (12). They found that dairy products had a negative correlation to both percent body fat (R= -3.54% + 1.04, P=0.001) and grams of body fat (R= -907.06g + 284.6, P= 0.003). Higher mean longitudinal calcium (mg/day) intake and more servings/day of dairy products were correlated with decreased body fat.

Clinical Trial Studies

Despite the findings from observational studies, the data from controlled clinical trials examining the effects of calcium and dairy have differing results regarding an association between calcium, weight loss, and body fat. Shapses et al designed three separate 25-wk randomized, double blind, placebo-controlled trials to examine whether calcium supplementation of 1000 mg/d during a weight loss intervention affects body fat or weight loss (14). Data were combined for 100 premenopausal and postmenopausal women who completed the study. Primary outcome measures were baseline-adjusted change in body weight and fat mass. No significant differences in change of body weight or fat mass change were found for placebo versus the calcium-supplemented groups in the compiled analysis (body weight, placebo -6.2 ± 0.7 versus calcium -7.0 ± 0.7 kg; fat mass, placebo -4.5 ± 0.6 versus calcium -5.5 ± 0.6 kg). Again, no significant differences between the placebo and the calcium groups were found in separate analysis of the trials. Calcium supplementation had no significant effect on amount of weight or fat lost by women advised to moderately restrict their diet for 25 weeks.

In a randomized, controlled trial Barr et al examined the influence of increased milk consumption in adults aged 55 to 85 (15). Subjects in the milk-supplemented group were advised to increase their milk intake by 3 cups/d. The milk-supplemented (n= 101) subjects as a group gained 0.6 kg more ($P < .01$) versus controls (n= 103). Furthermore, a review article of randomized trials evaluated the possible role of increased intakes of dairy products or calcium on body weight or composition in humans (16). Out of 26 trials, 9 studying dairy product supplementation and 17 involving calcium supplementation, only one study (using calcium) found significantly greater weight loss in the supplemented group. Interestingly, two studies conducted in older adults reported significantly greater weight gain in the dairy product groups. In the remaining trials, no significant differences in the change in body weight or composition were detected between treatment and control groups. The results of this review suggest that the data from existing randomized trials of dairy product or calcium supplementation provide little support for an effect in reducing body weight or fat mass.

In contrast, the possible effects of dairy and calcium supplementation on the acceleration of weight and fat loss in obese adults were examined in a clinical trial recently conducted by Zemel and colleagues (13). This was a 24 week randomized, placebo controlled trial, completed with 32 subjects (9 of the original 41 subjects were lost to dropout). 32 obese, otherwise healthy subjects were randomly assigned to one of

three diet groups: 1) low calcium, a control group with 0 to 1 servings of dairy foods/day, totaling 400 to 500 mg calcium/d, and a daily placebo supplement; 2) high calcium, identical to the control group, with the placebo replaced by an 800mg calcium carbonate supplement, totaling 1200 to 1300 mg calcium/d; or 3) high dairy, with 3 servings of dairy foods/day, totaling 1200 to 1300 mg/d, and a placebo supplement. All three diets provided a 500 kcal/d energy deficit. According to the study, the low calcium group lost 6.4 $\pm$ 2.5% of their body weight, compared to 8.6 $\pm$ 1.1% (26% increase) for the high calcium group, and 10.9 $\pm$ 1.6% (70% increases) for the high dairy group. They also report that the low calcium group lost 8.1 + 2.3% of their initial body fat, while the high calcium group lost 11.6 + 2.2%, and the high dairy lost 14.1 + 2.4%. These results are statistically significant ($p < 0.01$), and would suggest that increasing calcium and dairy intake increases weight and fat loss compared to reducing caloric intake alone.

However, further independent analysis of the data shows that the in low calcium group, body fat constituted a greater proportion of weight lost, at 72.9%, compared to 65.4% for the high calcium group, and 64.7% for the high dairy group. This was not mentioned in the paper, but may be of importance to individuals desiring to lose weight but not lean body mass. Additionally, there were statistically significant differences in initial body fat, 59.4 $\pm$ 4.7% for the low calcium group versus 48.4 $\pm$ 5.3% for high calcium and 50.7 $\pm$5.0% for high dairy. Potential differences in exercise level as well as caffeine intake, which were set for individual subjects but not across all groups, might have affected total energy expenditure. Having considered these issues, the overall results of the trial remain promising. Further studies with an increased number of subjects and longer duration may be beneficial.

Diet and Dairy: Future Considerations

Dairy products are an important part of a balanced diet, providing calcium to promote a variety of established health benefits. Yet despite recent promising findings, the possible affects of dairy products on weight loss and body fat reduction in humans including obese individuals are not fully clear. For example, do the proposed cellular mechanisms apply to any source of calcium or only to dairy products in particular? Will these possible benefits of dairy products be observed across a range of BMI values, or predominantly for obese individuals? Is there a minimum level of dairy consumption required and how would this vary among individuals?

The potential implications of these questions highlight the need for continued research regarding the role of calcium and dairy products. In the interim, a reasonable option for physicians and patients would incorporate a suitable combination of dairy products and calcium supplements as needed in consideration of each individual's needs to achieve and maintain health until more information concerning other possible benefits is known. With the number of existing studies as an indicator of scientific interest in this important issue, the answers may soon be found.

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