Yogurt and weight management\textsuperscript{1–4}

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ABSTRACT
A large body of observational studies and randomized controlled trials (RCTs) has examined the role of dairy products in weight loss and maintenance of healthy weight. Yogurt is a dairy product that is generally very similar to milk, but it also has some unique properties that may enhance its possible role in weight maintenance. This review summarizes the human RCT and prospective observational evidence on the relation of yogurt consumption to the management and maintenance of body weight and composition. The RCT evidence is limited to 2 small, short-term, energy-restricted trials. They both showed greater weight losses with yogurt interventions, but the difference between the yogurt intervention and the control diet was only significant in one of these trials. There are 5 prospective observational studies that have examined the association between yogurt and weight gain. The results of these studies are equivocal. Two of these studies reported that individuals with higher yogurt consumption gained less weight over time. One of these same studies also considered changes in waist circumference (WC) and showed that higher yogurt consumption was associated with smaller increases in WC. A third study was inconclusive because of low statistical power. A fourth study observed no association between changes in yogurt intake and weight gain, but the results suggested that those with the largest increases in yogurt intake during the study also had the highest increase in WC. The final study examined weight and WC changes separately by sex and baseline weight status and showed benefits for higher yogurt consumption for both weight and WC changes for higher yogurt consumption in overweight men, but it also found that higher yogurt consumption in normal-weight women was associated with a greater increase in weight over follow-up. Potential underlying mechanisms for the action of yogurt on weight are briefly discussed. \textit{Am J Clin Nutr} 2014;99(suppl):1229S–34S.

INTRODUCTION
Overweight and obesity lead to increased risk of many deleterious health outcomes, including cardiovascular disease, type 2 diabetes, hypertension, some cancers, and many other chronic conditions and result in a reduced life expectancy (1–4). Because of their comorbidities and associated disability, overweight and obesity are associated with considerable economic costs resulting from reduced working capability and increased health care expenditures (5). Diet plays a key role in long-term maintenance of body weight and body composition (6), but apart from affecting energy balance, we still have a limited understanding of the specific foods, nutrients, and other dietary constituents that might influence weight maintenance.

Dairy products comprise a major food group and are an important nutrient source in the American diet (7, 8). Nutritional qualities of dairy have been widely examined in observational studies and randomized controlled trials (RCTs)\textsuperscript{5} that target the change, management, or maintenance of body weight and adiposity (9–12).

Although yogurt and milk have a generally similar nutrient composition (13, 14), yogurt is a relatively unique dairy product. Because of its specific manufacturing procedures and fermentation, many nutrients, including protein, riboflavin, vitamin B-6, vitamin B-12, calcium, potassium, zinc, and magnesium, are more concentrated (ranging from 20% to >100%) in yogurt than in milk (15); and the acidity of yogurt increases the bioavailability of specific nutrients such as calcium (16). In a recent cross-sectional analysis in 6526 American adults, we found that yogurt consumers were more likely than those who did not consume yogurt to have a better overall diet quality and a higher potassium intake and were less likely to have inadequate intakes of riboflavin, vitamin B-12, calcium, magnesium, and zinc (17).

Yogurt also has more lactic acid and galactose but less lactose than milk (13, 14). In addition to increased protein concentrations, yogurt has higher concentrations of specific peptides and free amino acids than milk (13, 14). Moreover, probiotics in yogurt have possible health benefits (18, 19). Although there has been growing interest in yogurt’s relation to gut and immunologic function and aspects of cardiometabolic health (13–16), this remains understudied in relation to weight maintenance.

The primary purpose of this review is to summarize the existing human evidence on the relation between yogurt and the management and maintenance of body weight and composition. We also briefly explore potential underlying mechanisms. In

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\textsuperscript{5}Abbreviations used: CARDIA, Coronary Artery Risk Development in Young Adults; FFQ, food-frequency questionnaire; NHS, Nurses’ Health Study; RCT, randomized controlled trial; SU.VI.MAX, Supplementation en Vitamines et Mineraux AntioXydants; WC, waist circumference.

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assessing the evidence linking yogurt to weight and the potential mechanisms of action, it is important to consider yogurt in the context of overall dairy to determine whether the potential health benefits of yogurt are just a consequence of its being a dairy food or if there are health effects that are unique to yogurt.

**YOGURT CONSUMPTION AND WEIGHT AND FAT LOSS: EVIDENCE FROM CLINICAL TRIALS**

A recent meta-analysis by Chen et al (11) summarizes the results from 29 RCTs that examined the effects of various dairy interventions on changes in body weight and fat mass. Their findings suggested that, overall, dairy interventions resulted in no significant weight loss but a modest reduction in fat mass. However, when the trials were stratified on the basis of whether or not the treatment diets were energy restricted, there was a modest effect of dairy interventions (compared with control groups) on weight and fat loss when used as part of an energy-restricted diet. Dairy interventions did not promote more loss in weight or fat mass than did control dietary regimens among the trials with ad libitum interventions.

Among these 29 RCTs, yogurt was included as part of the intervention in 15 trials. A combination of yogurt and milk was used as the intervention in 2 trials; 11 allowed participants to choose freely from yogurt, cheese, and milk; but only 2 trials considered yogurt alone as the dairy intervention, a 2005 trial by Zemel et al (20) and a 2011 trial conducted by Thomas et al (21). Both of these were energy-restriction trials. Specifically, Zemel et al (20) randomly assigned 34 obese individuals to a yogurt intervention [a 6-ounce (170-g) serving of fat-free yogurt 3 times/d] or a control diet [including a 6-ounce (170-g) gelatin-based dessert placebo 3 times/d] providing, at most, 1 serving dairy/d as part of a 12-wk, 500-kcal/d deficit diet. The yogurt intervention resulted in a 33% greater reduction in body weight, a 60% greater loss of body fat, and a 31% reduction in the loss of lean body mass than did the control diet. Thomas et al (21) randomly assigned 29 overweight women who were engaged in a resistance-training program to 2 6-ounce (170-g) fat-free yogurt supplements (3 times/wk) or 2 6-ounce (170-g) isooenergetic sucrose beverages (3 times/wk) as part of a 250-kcal/d energy-deficit diet for a period of 16 wk. Differences in loss of weight, total fat, waist circumference (WC), sagittal diameter, and trunk fat were not significantly different between the yogurt and control groups in this trial.

This summary shows the paucity of intervention data relating yogurt to weight loss and weight maintenance. There are only 2 RCTs (20, 21), one of which shows a significant benefit of yogurt (20), whereas findings from the second were equivocal (21). There are differences between these 2 trials that may be responsible for the discrepant findings, such as differences in participants’ weight, control diets, and length of follow-up. However, perhaps the most important difference was the yogurt dose. The yogurt intervention in the trial by Thomas et al (21) provided 1020 g fat-free yogurt per week, whereas the weekly dosage provided in the study by Zemel et al was 3.5-fold higher (20). One important limitation of both of these RCTs in assessing the unique effect of yogurt relative to other dairy products was the lack of a comparable dairy control. Without such a control, we cannot confidently attribute the observed effects on weight and body composition to any special properties of yogurt.

**YOGURT CONSUMPTION AND WEIGHT AND WC: EVIDENCE FROM OBSERVATIONAL STUDIES**

In addition to the RCTs examining the effect of dairy on weight, there is also an extensive observational literature on dairy and weight management. Louie et al (9) published a systematic review of prospective observational studies of dairy and weight gain in 2011. They identified 19 prospective cohort studies of dairy intake and change in weight or body fat; only 3 considered yogurt as a separate item (22–25). Subsequent to publication of this review, 2 additional studies were published that considered yogurt separately (25, 26). These 5 prospective observational studies are summarized in Table 1. Because yogurt (and in some cases dairy) was not the focus of these studies, some of the details with regard to yogurt consumption in these 5 articles were limited.

Pereira et al (22) based their report on a 10-y follow-up of >2700 participants from the Coronary Artery Risk Development in Young Adults (CARDIA) Study, a sample of young adults (mean age: 25 y) from 4 large US metropolitan areas. More than half of the participants were black. A 28-d diet history questionnaire was used at baseline to collect the frequency of consumption for selected foods. The median frequency of yogurt intake in whites was 0.3 times/wk for overweight participants and 0.5 times/wk for normal-weight participants; the median consumption of yogurt was 0 times/wk in black participants irrespective of weight status. Drapeau et al (23) examined food groups and weight change over an average follow-up of 5.9 y in the Quebec Family Study, a small cohort of 248 parents and their offspring (≥18 y) from Quebec, Canada. The mean age of this cohort was 40 y. Yogurt intake was assessed at baseline and at the final study visit by using a 3-d diet record, but the authors did not provide information on the frequency of yogurt consumption in this population. Vergnaud et al (24) examined yogurt intake and change by using data from the Suplementation en Vitamines et Mineraux Antioxydants (SU. VI.MAX) trial, a large antioxidant vitamin and mineral intervention study that recruited participants from throughout France. They based their analysis on 13,017 participants (mean age: 51 y) with an average follow-up of 6 y. Information on dietary intake was collected at baseline via several 24-h dietary recalls. Mean yogurt intakes were 0.52 and 0.67 servings/d (125 g yogurt/ servings) in men and women, respectively. Mozaffarian et al (25) used data for >120,000 men and women from the 3 Harvard health professionals’ cohorts: the Nurses’ Health Study (NHS; 20-y follow-up), NHS-II (12-y follow-up), and the Health Professionals Follow-Up Study (20-y follow-up). Mean ages were 52, 38, and 51 y in the NHS, NHS-II, and Health Professionals Follow-Up Study, respectively. These investigators excluded individuals who were obese or had any chronic disease. Dietary intake was repeatedly assessed during follow-up in these 3 cohorts by Harvard food-frequency questionnaires (FFQs) (27). Although yogurt intake was assessed by the FFQ, the authors did not present information on the usual amounts of yogurt consumed by members of these cohorts in their article. Finally, our recent longitudinal analysis of the Framingham Heart Study offspring cohort (26) included 3440 participants with 11,683
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<tr>
<td><strong>Age (y)</strong></td>
<td>25 (18–30)&lt;sup&gt;2&lt;/sup&gt;</td>
<td>40 (18–65)</td>
<td>51 (35–60)</td>
<td>52 (NHS), 38 (NHS-II), 51 (HPFS)</td>
<td>Framingham Heart Study Offspring Cohort</td>
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<td><strong>Study size (n)</strong></td>
<td>2056 [BMI (in kg/m&lt;sup&gt;2&lt;/sup&gt;) &lt;25]; 675 (BMI ≥25)</td>
<td>248</td>
<td>13,017</td>
<td>120,877</td>
<td>3440</td>
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<td><strong>Follow-up (y)</strong></td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>20 (NHS), 12 (NHS-II), 20 (HPFS)</td>
<td>13</td>
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<td><strong>Diet assessment</strong></td>
<td>28-d FFQ (baseline, 7 y)</td>
<td>3-d diet records (baseline, 6 y)</td>
<td>Six or more 24-h dietary recalls</td>
<td>3–5 FFQs</td>
<td>4 FFQs</td>
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<td><strong>Yogurt intake</strong></td>
<td>Median (servings/wk): 0.00 (blacks), 0.45 (whites) Not reported</td>
<td>Not reported</td>
<td>Mean (servings/d): 0.52 (men), 0.67 (women)</td>
<td>Not reported</td>
<td>Mean (servings/wk): 0.86 at baseline</td>
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<tr>
<td><strong>Results</strong></td>
<td>BMI &lt;25: not reported 6-y Δyogurt not associated with Δweight</td>
<td>6-y Δyogurt not associated with Δweight</td>
<td>Δ weight 1.1 kg less and ΔWC 1.3 cm less for &gt;1.1 servings/d vs &lt;0.2 servings/d (&lt;P = 0.01 and &lt;P = 0.03)</td>
<td>4-y Δweight 0.82 pounds less for each yogurt serving/d; similar association seen in all 3 cohorts</td>
<td>ΔWeight 0.09 kg/y less for ≥3 servings/wk vs &lt;1 serving/wk (&lt;P = 0.03); ΔWC 0.14 cm/y less for ≥3 servings/wk vs &lt;1 serving/wk (&lt;P = 0.008)</td>
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<sup>1</sup> CARDIA, Coronary Artery Risk Development in Young Adults Study; FFQ, food-frequency questionnaire; HPFS, Health Professionals Follow-Up Study; NHS, Nurses’ Health Study; SU.VI.MAX, SUpplementation en VItamines et Mineraux AntioXYdants; WC, waist circumference; Δ, change.

<sup>2</sup> Mean; range in parentheses (all such values).
observations and a median follow-up of 12.9 y. Data on dietary intake and anthropometric measurements were collected at baseline and at 3 follow-up examinations. The Harvard FFQ (27) was used to assess participants’ usual dietary intake. At baseline, the mean yogurt intake was 0.86 servings/wk. By the end of follow-up, that intake had increased to 1.35 servings/wk. A standardized serving size of yogurt on the FFQ was 1 cup (227 g).

The findings varied across these 5 studies (Table 1). Results from the CARDIA study (22) reported that the OR for 10-y incident obesity associated with each additional serving yogurt/d was 0.47 (95% CI: 0.16, 1.43) among young adults who were overweight at baseline after adjustment for numerous lifestyle and dietary factors. These results were inconclusive because of the low power to detect an association in the overweight participants. The authors did not present the results for normal-weight participants. The Quebec Family Study (23) found no association between change in yogurt consumption and weight change but observed a positive association with the change in WC after adjustment for age, initial weight or WC, and change in physical activity. These investigators observed that an increase of 1 serving yogurt/d from baseline to the end of follow-up was associated with a 0.42-cm increase in WC over the 6-y follow-up period (P = 0.02). The SU.VI.MAX trial examined yogurt intake and changes in weight and WC by participants’ sex and weight status (24). Significantly less gain in weight and WC was found in overweight men but not in normal-weight men. Overweight men who consumed >1.1 serving yogurt/d gained, on average, 1.1 kg (55%) less body weight and 1.3 cm (80%) less WC over the 6-y follow-up compared with overweight men who consumed <0.2 servings/d (P = 0.01 and P = 0.03, respectively). In contrast, there was no association seen between yogurt and weight change in overweight women whereas normal-weight women who consumed >1.3 servings yogurt/d gained, on average, 0.7 kg (53%) more weight than did their counterparts who consumed <0.4 servings yogurt/d over the 6-y follow-up (P = 0.04). There was no association between yogurt consumption and WC among women irrespective of baseline weight (24). Mozaffarian et al (25) reported that the 4-y weight gain was, on average, 0.82 pounds (~0.37 kg) less with each additional serving of yogurt/d consumed (P < 0.001); this inverse association was similar in all the 3 cohorts that they examined. Finally, in our recent longitudinal analysis of the Framingham Heart Study offspring cohort (26), we observed that participants who consumed ≥3 servings yogurt/wk gained 0.09 kg less body weight/y and 0.14 cm less WC/y than those consuming <1 serving yogurt/wk after adjustment for sex, age, smoking status, physical activity, weight or WC at the start of each examination interval, energy intake, and overall diet quality assessed by the Dietary Guidelines Adherence Index score (28) (P = 0.03 and 0.008 for weight and WC, respectively). We observed similar associations with total dairy and both weight change (P = 0.04) and WC change (P = 0.05). However, it should be noted that the similar observations seen for total dairy and yogurt intake are based on ≥3 servings/d for total dairy but only ≥3 servings/wk for yogurt, suggesting similar potential benefits at a much lower intake of yogurt. Moreover, after yogurt from total dairy intake was excluded, these associations with total dairy intake were weakened and were no longer statistically significant.

There are no clear reasons for the lack of consistent findings between studies. The CARDIA study (22) findings for overweight individuals are underpowered because of the relatively small number of overweight participants and the small proportion of yogurt consumers in this young adult cohort. The Quebec Family Study (23) was the only one of these studies to base intake on 3-d diet records, which may have led to greater misclassification of yogurt intake given the episodic nature of yogurt consumption in North America. Also, the authors of this study took a different analytic approach to examine this relation. Rather than relating absolute intake amounts to changes in weight or WC, they examined the association between the change in yogurt and change in weight and WC over the study’s follow-up period. The change in intake may not relate to the typical (ie, average) intake during follow-up. The SU.VI.MAX trial (24) investigators stratified their sample by sex and baseline weight status. Even though the test for interaction between baseline weight, sex, and yogurt consumption was marginally significant (P = 0.04), it is possible that the variation in results observed within these stratified analysis was spurious or, as the authors of this study suggested, the differences could be a consequence of different dietary patterns for men and women and for body weight status. More large prospective studies, particularly studies in populations with higher yogurt consumption, are warranted to help clarify the role of yogurt in maintaining a healthy weight.

POTENTIAL UNDERLYING MECHANISMS

Although there is limited human evidence on the role of yogurt in weight change, there is no shortage of hypothesized mechanisms for the effect of yogurt on weight and fat mass. As mentioned previously, yogurt is a concentrated dairy product, providing a greater amount of various water-soluble nutrients (eg, calcium) per serving size than do milk drinks (15). In addition, some nutrients in yogurt are more bioavailable than in other forms of dairy (29). Calcium and other nutrients (eg, whey and casein proteins, bioactive peptides, amino acids, and fatty acids), which are abundant in yogurt (13, 14), have been shown, or have been proposed, to facilitate loss of weight and fat mass (30–32). Higher calcium intake is thought to reduce lipogenesis and stimulate lipolysis and lipid oxidation through its effects on intracellular calcium concentrations, mediated primarily by calcitriol concentrations (30). It has been shown that the increase in circulating calcitriol resulting from low-calcium diets can stimulate calcium influx into adipocytes. Increased intracellular calcium, in turn, promotes adiposity as it stimulates lipogenic gene expression and lipogenesis and inhibits lipolysis, leading to increased lipid in adipocytes. Calcium may also interact with other nutrients and components of dairy foods and with fermentation products because sources of dairy calcium appear to have a greater effect on weight change than does supplemental calcium, perhaps acting synergistically with bioactive peptides and branch chain amino acids (30). The potential roles of calcium and other dairy bioactive compounds in weight maintenance are not unique to yogurt, but, as noted above, the amount and availability of calcium and some of the other potential bioactive constituents of dairy are generally greater in yogurt than in equal amounts of milk.

There is also much recent evidence supporting a role of gut microbiota in weight control (33–35). As a fermented dairy product, yogurt is a good source of probiotic bacteria that may favorably alter the gut microbiota. The dominant gut microbiota of obese mice or humans differs substantially from that of their
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...leak counterparts and appears to use energy from diets in a more efficient manner, which may promote weight gain (33, 34). Such differences in the energy-harvest capacity of microbiota are transmissible between obese and lean donors (34). It is believed that the bacteria in probiotic yogurt can enhance the growth of beneficial intestinal microbiota and influence gut function and distant tissues through regulation of the immune system (36); such effects may result in weight loss or in prevention of weight gain. A recent mouse study showed that supplementing with a probiotic yogurt inhibited the weight gain resulting from a westernized diet and aging (35). The authors further examined the underlying mechanisms and showed that a bacterium purified from yogurt was able to inhibit fat accumulation via an adaptive immune cell mechanism and that a preexisting diverse gut microbial community was essential for this good bacterium to exert its beneficial effect (35).

Another underlying mechanism may include the potential difference in satiety resulting from the consumption of yogurt compared with other drinks or dairy products. Small short-term RCTs have shown that yogurt is more satiating than other selected foods such as fruit drinks, chocolate bars, and crackers; however, this effect does not translate into lower subsequent energy intakes (37–39).

CONCLUSIONS

Although there is a large body of data that relates dairy intake to weight management, we still know little about the specific role that yogurt might play and whether any beneficial effects of yogurt are unique to its specific properties or merely attributable to the fact that it is a dairy food. As we accumulate additional evidence for or against a benefit of yogurt consumption on weight management, the uncertain weight benefits of yogurt should not deter recommendations for including yogurt as part of a healthy diet, because it is a nutrient-dense, lower-calorie food that can help many Americans meet the dairy recommendations of the 2010 Dietary Guidelines for Americans (40).

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