Current Cardiovascular Risk Reports (2021) 15: 14
https://doi.org/10.1007/s12170-021-00676-6

OBESITY AND DIET (G. RAO, SECTION EDITOR)

The Impact of Dairy Intake on Adiposity and Satiety in Adults

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Accepted: 28 May 2021 / Published online: 20 June 2021

Abstract

Purpose of Review The 2020 Dietary Guidelines for Americans (DGA) recommends that American adults consume 2 to 3 daily servings of dairy foods as part of healthy dietary patterns. The DGA's recommended dietary patterns are intended to meet nutrient needs and reduce the risk of chronic diseases, including overweight and obesity. However, the evidence reviews that the 2020 DGA is based on, the 2020 Dietary Guidelines Scientific Advisory Report, did not assess the body of evidence linking individual foods to adiposity. The purpose of this review is to assess the evidence published in the last 10 years on dairy consumption, adiposity, and satiety.

Recent Findings The twenty studies included in this review, primarily randomized controlled trials, include interventions with the dairy foods recommended by the DGA—milk, cheese, and yogurt—of varying fat levels (whole fat, reduced fat (2%), low fat (1%), and fat free). Most of these studies were conducted in individuals who were overweight or had obesity at baseline. Therefore, these studies do not measure the impact of eating dairy foods on prevention of adiposity or obesity. Instead, they focus on whether dairy foods support weight loss/weight maintenance or how they affect satiety and prospective food consumption.

Summary Overall, recent evidence indicates that consuming dairy foods does not increase risk of overweight or obesity in adults but also does not protect against adiposity. Solid and semi-solid dairy foods like cheese and yogurt may be more satiating than milk and other beverages, though more research is needed to confirm these findings.

Keywords Dairy · Adiposity · Overweight · Obesity · Satiety · Weight loss

Introduction

One approach that the field of nutrition science has adopted to understand the dietary drivers of overweight and obesity is to study the associations between the development of adiposity and intake of a specific food or food group. Accordingly, many studies have investigated the link between consuming dairy foods like milk, cheese, and yogurt with markers of adiposity. A body of research has also been dedicated to the links between consuming certain food groups, including dairy foods, and satiety, which drives food intake.

This article is part of the Topical Collection on *Obesity and Diet*

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Previous reviews and meta-analyses on the associations between dairy intake and adiposity report conflicting results. A meta-analysis of randomized clinical studies published by Benatar et al. in 2013 [1] found that, while interventions that provided either low-fat or whole-fat dairy foods increased body weight, there was not a significant impact of either the low- or whole-fat dairy intake on other cardiometabolic outcomes including waist circumference (WC). However, this meta-analysis included studies that grouped butter, cream, and ice cream among "dairy foods," which differs from the dairy foods recommended as part of healthy dietary patterns in the most recent official US dietary guidance, the 2020 Dietary Guidelines for Americans (DGA) [2]. In contrast, a systematic review of prospective cohort studies by Louie et al. [3] indicated that consuming dairy foods seemed to have a protective effect on the risk of overweight and obesity in children and adults. Another systematic review of studies on yogurt and weight management [4] indicated that there was not a significant impact of yogurt consumption on weight loss. However, Eales et al. indicated that yogurt may be connected to a lower

BMI, lower body weight, less weight gain, a smaller WC, and lower body fat. Both systematic reviews [3, 4] stated that there was insufficient data to determine a causal relationship.

Since 2005, the DGA has recommended that Americans ages 9 and older consume 3 servings of dairy foods as part of healthy eating patterns intended to be protective of chronic diseases and health conditions, including overweight and obesity [2, 5–7]. However, while these recommendations were carried through in the 2020 DGA, the evidence review that the 2020 DGA is based on did not actually assess the evidence on specific foods and risk of obesity, focusing instead on overall eating patterns and their links to health outcomes such as excess weight gain. Because the recommendations in the 2020 DGA were based on dietary patterns research versus studies on individual foods, the purpose of this review is to assess the literature from the past 10 years on the impact of consuming dairy foods on adiposity and satiety [2].

Methods

This review focused on studies with interventions that included the dairy foods (milk, cheese, and yogurt) recommended by the DGA but was not restricted by fat level, so studies including whole-fat, reduced-fat (2%), low-fat (1%), and fat-free products were all eligible for inclusion. Trials that utilized dairy products fortified with nutrients or dietary components aside from vitamin A or vitamin D (standard fortificants for dairy foods in the USA) were not considered, as these products are not representative of typically available and consumed dairy foods in the USA. Trials conducted in individuals with multiple metabolic abnormalities and conditions, including the metabolic syndrome, were not included. Studies with participants who had obesity or type 2 diabetes but were otherwise generally healthy were included as these individuals are representative of the general adult population in the USA.

Search Strategy

This review used the following search terms in PubMed to identify articles: overweight OR adiposity OR abdominal adiposity OR abdominal obesity OR body mass index AND adult AND dairy product. Results were further filtered to include only those publications that describe clinical trials conducted in humans, with a full-text available, conducted in the last 10 years, published in the English language, and in adults ages 19 and older. An initial query yielded 260 studies. After a title review to remove duplicates and studies not fitting the criteria for this review, 92 studies remained, and after reviewing abstracts, 38 studies remained. Following a full-text review, 19 studies from the original query were included in this review. In addition to the studies obtained from the PubMed query, one additional study was added during the full-text review stage [8]. Included studies had to assess interventions or effects of milk, cheese, or yogurt, compared to a non-dairy control or placebo on an adiposity- or weight-related outcome including BMI, body composition, body weight, WC, waist-to-hip ratio (WHR), or a satiety-related outcome such as energy intake and subjective ratings of satiety using visual analog scales (VAS). Several studies on adiposity, including many of the studies in this review, evaluate multiple outcomes including postprandial glycemia and bone health markers, among others. In this review, only those outcomes relevant to adiposity and satiety will be discussed.

Results

The results of this literature review have been divided into two sections: studies that assess the links between consuming dairy foods with markers of adiposity and studies that assessed the impact of consuming dairy foods on satiety.

Body Weight and Body Composition

Fifteen studies assess the links between consuming dairy foods and markers of adiposity. These studies include 4 publications [8–11] on randomized crossover trials from 3 studies, 9 randomized controlled trials [12–20], one substudy of a randomized controlled trial [21], and one observational study [22]. These studies have also been summarized in Table 1.

The 4 randomized crossover trials included in this review all compared a high-dairy diet to a low-dairy diet in individuals who were overweight or had obesity and reported few differences in adiposity-related outcomes between the two interventions. In one randomized crossover trial [11], 45 overweight participants between 45 and 65 years of age consumed a high-dairy diet (5–6 servings of dairy foods daily) for 6 weeks and a low-dairy diet (less than 1 serving of dairy foods daily) with a 4-week washout in between treatments. While participants were advised to keep their caloric intake consistent, caloric intake during the high-dairy diet was slightly higher. Body weight was lower after the low-dairy diet ($p=0.012$), but there were no differences in WC, hip circumference (HC), body fat percentage, or lean mass between the two treatments [11]. A secondary outcome analysis of this same trial [10] with data from 52 participants reported similar results. Total energy intake was higher during the high-dairy diet ($p=0.021$). And, after the high-dairy diet, participants had a slightly higher body weight ($p=0.008$) and higher BMI ($p=0.007$), but there were no differences in HC, WC, or total body fat between the two interventions.

Another randomized crossover trial [9•] compared 6 months of high- and low-dairy diets on 23 healthy participants with BMIs within the overweight to obese range. Participants consumed 4 servings per day of dairy foods (high-dairy diet)

Table 1 Summary of studies assessing dairy intake with measures of adiposity in adults

Author and reference	Type of study	Participants	Outcome measures	Intervention or exposure	Results
Bendtsen et al. [15•]	Randomized controlled trial	N=52 males and females 44 ± 1 years (y) with habitual daily calcium intake <800 mg per day; body mass index (BMI): 30.6 ± 0.3 kg/m^2	• Weight • Waist circumference (WC) • Hip circumference (HC) • Body composition	Participants assigned to a hypocaloric diet (500 calorie deficit) either high in dairy or low in dairy for 24 weeks. The high-dairy diet included 1500 or more mg of calcium per day, with 1200 mg from dairy foods and the rest from other foods. Low-fat dairy was encouraged to meet energy requirements. The low-dairy diet included no more than 600 mg of calcium per day.	At the end of the 24-week trial, there was no difference in weight loss, fat mass, fat-free mass, or WC between the two groups. The low-dairy group had a higher decrease in HC.
Champagne et al. [21]	Substudy of randomized controlled trial	N=828 males and females 56.0 y (on average) who lost at least 4 kg as part of a clinical weight loss trial. Baseline BMI: 30.6 ± 0.3 kg/m^2	• Servings of fruits/-vegetables, dairy foods, dietary fiber • Weight	Adults were assigned to a 6-month weight loss plan followed by a 30-month weight maintenance plan and asked to complete food frequency questionnaires at 12- and 30-month post-trial.	Participants who increased low-fat dairy intake did not lose more weight but were better able to maintain their weight over a 30-month period. Substituting carbohydrates or protein for fat, substituting protein for carbohydrates, and increasing fruit and vegetable intake were associated with greater weight loss.
Celik et al. [14]	Randomized controlled trial	N= 65 premenopausal females 33.10 ± 6.18 y; baseline BMI: between 30 and 39.9 kg/m^2	• Weight • Body composition • WC • HC • BMI	Women were assigned to one of three hypocaloric diet groups (1000 kcal deficit): high-dairy diet (30 g low-fat cheese and three glasses milk daily), low dairy (30 g low-fat cheese and one glass milk daily) of a control diet (30 g low-fat cheese) for 12 weeks.	No differences between groups with any anthropomorphic measures, though all subjects lost weight and had lower BMI, WC, weight-to-height ratio, body fat percentage, and body fat mass after 12 weeks.
Crichton et al. [8]	Randomized crossover trial	N=36 males and females 18 to 71 y with a habitually low intake of dairy (less than 2 servings a day); baseline BMI: 31.5 ± 0.9 kg/m^2	• Weight • Body composition • WC • HC • BMI	Participants were assigned to follow high-dairy diet (4 servings/day of reduced-fat dairy) and a low-dairy control diet (1 or fewer serves of dairy/day) for 6 months each. One serving of dairy foods was defined as 250 mL of milk; 190 g custard; 175–200 g yogurt; 2 slices of cheese (40 g) of cheese; 100 g cottage cheese; 30 g ricotta/cream cheese/cream; 90 g ice cream; 11 g butter or margarine.	Mean energy intake was higher during the high-dairy phase than during the low-dairy control. More calories from both fat and protein were consumed during the high-dairy section. There were no differences in WC, body weight, HC, BMI, total body fat, or abdominal fat between the two groups.
Eelderink et al. [11]	Randomized crossover trial	N= 45 males and females 58.9 ± 4.3 y; baseline BMI: 27.9 ± 1.9 kg/m^2	• Weight • Body composition • WC • HC	Participants completed 6 weeks each on a high- and a low-dairy diet (5–6 dairy portions versus less than 1 dairy portion) with a 4-week washout. Portion of dairy included 200 g	Body weight was lower after the low-dairy diet but there were no differences in WC, HC, body fat percentage, or lean mass between the two groups.

Table 1 (continued)

Author and reference	Type of study	Participants	Outcome measures	Intervention or exposure	Results
				semi-skimmed yogurt, 30 g reduced-fat cheese, 250 mL semi-skimmed milk or buttermilk.	
Faghih et al. [19]	Randomized clinical trial	N= 100 females 20 to 50 y; baseline BMI: 20 to 40 kg/m^2	• Weight •WC •HC • BMI •Body composition • Waist-to-hip ratio (WHR)	After a 2-week run-in, participants consumed one of 4 interventions for 8 weeks: control diet with 500 kcal deficit, identical hypocaloric diet with 800 mg/day calcium supplement, same hypocaloric diet with 500 kcal deficit and three servings (220 mL each) of low-fat milk, or the hypocaloric diet with 3 servings of calcium-fortified soy milk. Each group received comparable amounts of macronutrients.	Body weight, BMI, WC, WHR, body fat mass, and percent body fat mass decreased in all groups. Including milk in the hypocaloric weight reduction diet led to greater reductions in BMI (compared to the controls), weight (compared to the controls), WC (compared to the control) and WHR (compared to both the control and soy groups), and % waist change (compared to soy and controls). Including soy in the diet also reduced WC and WHR compared to controls.
Ilich et al. [12•]	Randomized control trial	N= 100 females 55.8 ± 4.3 y; baseline BMI: 31.5 ± 5.1 kg/m^2	• Weight • WC • HC • Abdominal circumference • Body composition	Women were randomized into one of 3 6-month energy-restricted weight loss diets (85% of energy needs): dairy diet with 4–5 servings of low-fat dairy per day, supplement diet with calcium and vitamin D pills, or placebo pills. Both dairy and supplement interventions provided approximately 1500 mg per day of calcium and 600 IU per day of vitamin D.	The dairy group had the greater percentage decrease in WC, HC, and abdominal circumference, though not all differences were significant. Both the dairy and supplement groups had greater decreases in body fat compared to the placebo.
Josse et al. [17]	Randomized control trial	N=90 females 19–45 y; baseline BMI: 27 to 40 kg/m^2	• Weight • WC • HC • Body composition • BMI • Visceral adipose tissue (VAT) volume	Participants were divided into 3 groups: high-protein/high-dairy (6–7 dairy servings per day); adequate-protein/medium--dairy (3–4 servings per day); adequate-protein/low-protein (0–1 servings per day) for 16 weeks. All diets were hypocaloric by 500 calories per day and participants were asked to expend 250 kcal of energy in a workout session daily with 2 days per week of resistance exercise. A serving of dairy was defined as 250 mL of milk, 50 g cheese, or 175 mL of yogurt.	The high-protein/high-dairy group lost more fat mass and gained more lean mass than the other two groups over weeks 8–16. The low-dairy group lost lean mass. The groups consuming medium or high amounts of dairy foods had more favorable outcomes in body composition: greater fat mass loss, greater visceral fat loss, and greater lean mass gain.
Maltais et al. [16]	Randomized controlled trial	N= 26 males 65 ± 5 y; baseline BMI: <30 kg/m^2; participants had	• Weight • Body composition	Participants all completed 4 months of resistance exercise and were randomized into 3	Only the dairy group lost significant fat mass by the end of 4 months and

Table 1 (continued)

Author and reference	Type of study	Participants	Outcome measures	Intervention or exposure	Results
		appendicular lean mass lower than 10.75 kg/m^2		groups for postexercise shakes: control (rice milk), chocolate milk with milk powder, or soy beverage with amino acid powder. All shakes were 375 mL and 280 kcal.	increased their lean mass-to-fat mass ratio. Lean mass increased in all groups. Body weight increased in the non-dairy shake group only. There were no significant increases in calcium or calorie intake during the intervention.
Maersk et al. [13]	Randomized controlled trial	N= 47 males and females 20 to 50 y; baseline BMI: 26 to 40 kg/m^2; baseline blood pressure <160/100 mmHg	• Weight • Body composition • Total fat mass • Ectopic fat deposition (liver and muscle tissue) • Fat distribution	Participants assigned to drink 1 L of one of 4 different treatments: regular cola, an isocaloric serving of semi-skimmed milk, diet soda (aspartame sweetened), or water for 6 months.	Total fat mass did not differ between the 4 groups. The relative changes between baseline and 6 months were higher in the regular cola group than in the other 3 groups for: liver fat, skeletal muscle fat, and VAT. There were no differences between the semi skim milk, diet cola, and water groups with these measures. There were no significant differences in change in body weight or fat mass between the 4 groups. Both cola and milk increased amount of subcutaneous abdominal adipose tissue (SAAT), and the noncaloric beverages decreased SAAT.
Palacios et al. [18]	Randomized controlled trial	N= 25 males and females 21 to 50 y; baseline BMI: ≥30 kg/m^2; baseline calcium intake <700 mg/day	• Weight • BMI • Body Composition • Trunk fat mass • Trunk fat percentage	Participants were assigned to either a high-dairy diet (4 servings per day of low-fat milk, low-fat cheese, low-fat yogurt), a diet with 700 mg calcium from diet and 600 mg of calcium from supplements, or a placebo for 21 weeks. Participants were asked to keep their diets isocaloric with their pre-intervention diets.	There were no significant impacts between groups on any adiposity-related measures.
Radavelli-Bagatini et al. [22]	Observational study	N=1,456 females 75.2 ± 2.7 y; baseline BMI: 27.2 ± 4.7 kg/m^2	• Body composition • Appendicular skeletal muscle mass	Dairy foods (defined as milk, cheese, and yogurt) given as servings per day were assessed by an FFQ at baseline. A serving of dairy foods was defined as 250 g milk, 200 g yogurt, 40 g hard, form, soft, low-fat cheese, or 120 g cottage and ricotta cheese.	Women in second and third tertiles of dairy intake had greater whole body lean mass and appendicular skeletal muscle mass compared with the first tertile both before and after multivariate adjustment. There were no differences between 3 tertiles with body fat mass.
Rideout et al. [9•]		N= 23 males and females 53 ± 12.26 y (range 22 to 72	• Weight	Participants were placed in one of two treatment groups:	There were no significant differences in body

Table 1 (continued)

Author and reference	Type of study	Participants	Outcome measures	Intervention or exposure	Results
	Randomized crossover trial	y); baseline BMI: 31.86 ± 3.01 kg/m^2	• Body composition • WC • Energy expenditure	high-dairy group (4 servings/day of low-fat dairy foods: 250 mL skim milk, 175 g yogurt) or a low-dairy group (no more than 2 servings/day) for 6 months with no washout. Participants were asked to incorporate dairy foods into their normal diets to keep their trial diets isocaloric with their pre-intervention eating patterns.	weight, WC, total body fat, or abdominal body fat between the two interventions (endpoint of the low-dairy diet versus the endpoint of the high-dairy diet).
Rietsema et al. [10]	Randomized crossover trial	N= 52 males and females 58.6 ± 4.8 y; baseline BMI: 28.0 ± 1.9 kg/m^2	• Weight • WC • Body composition • Energy intake	Participants were randomized to either a "low-high" sequence or a "high-low" sequence, with each segment lasting 6 weeks. During the low-dairy diet, participants consumed <1 serving of dairy foods each day, and during the high-dairy diet, participants consumed 5 servings of dairy per day, if female, and 6 portions of dairy per day, if male. A portion of dairy was defined as 250 mL of semi-skimmed milk or buttermilk, 200 g semi-skimmed yogurt, or 30 g reduced-fat cheese.	After the high-dairy diet, participants had a slightly higher body weight (p=0.008) and higher BMI (p=0.07) but no differences in WC and total body fat. Total energy intake was also higher during the HDD than during the LDD (p=0.021).
Witbracht et al. [20]	Randomized controlled trial	N= 51 females 20 to 45.9 y; baseline BMI: 28 to 37 kg/m^2; baseline dairy intake ≤238 mL/day milk, ≤43.0 g/day cheese, or ≤227.0 g/day yogurt with total calcium intake had to be ≤0.6 g/day.	• Weight • BMI • WC • Body composition • Android fat • Gynoid fat	Following a 3-week baseline period, women were assigned to consume adequate-dairy food (at least 711 mL/day of milk) or low-dairy food (less than 238 mL/day of milk) over a 12-week period as part of a hypocaloric dietary intervention.	Baseline and end of intervention body weight, fat mass, BMI, and WC did not differ between the adequate- and low-dairy intervention groups.

or no more than 2 servings per day of dairy foods (low-dairy diet), while keeping their diets overall isocaloric with their pre-intervention eating patterns. There were no significant differences in body weight, WC, total body fat percentage, or abdominal body fat percentage after the two interventions. A similar randomized crossover trial [8] also had participants consume high- and low-dairy diets for 6 months each. The 36 adults ages 18 to 75 in this study were overweight or had obesity and typically consumed little dairy. Participants consumed 4 servings per day of reduced-fat dairy for 6 months and a low-dairy control diet (1 or fewer servings of dairy per day) for 6 months. Mean energy intake was higher during the high-dairy phase (p=0.004). However, after 6 months, there were no differences in WC, body weight, HC, BMI, total body fat, or abdominal fat. The authors concluded that dairy foods can be incorporated into the diet without weight or fat gain [8].

Results of the non-crossover studies reported some benefits to the dairy interventions compared to the controls. A trial of 135 postmenopausal overweight women or women with obesity found that women consuming 4–5 servings per day of low-fat dairy foods for 6 months as part of an energy-restricted weight loss diet saw a greater percentage decrease in WC, HC, and abdominal circumference than women either consuming a low-dairy diet (with calcium and vitamin D supplements) or taking placebo pills, though not all of the differences reached statistical significance [12•]. A similar trial conducted in 100 premenopausal women who were overweight or had obesity assigned participants to consume one of 4 hypocaloric diets for 8 weeks: control diet, control diet with 800 mg per day calcium supplement, a diet with three daily servings of low-fat milk, or a diet with 3 daily servings of calcium-fortified soy milk [19]. Body weight, BMI, WC, WHR, body fat mass, and percent body fat mass decreased in all groups, but including 3 servings of milk in the weight reduction diet led to greater reductions in BMI (compared to the control; p<0.01), weight (compared to the control; p<0.01), WC (compared to the control; p<0.01), and WHR (compared to the control; p<0.01). Changes in WC and WHR were also higher in the soy milk groups relative to the control (p<0.05).

A substudy of a randomized weight loss trial and an observational study also showed some benefits to consuming dairy foods for healthy weight maintenance. Champagne et al. [21] conducted a substudy with 828 participants who successfully achieved at least a 4-kg weight loss during a randomized controlled clinical trial. According to food frequency questionnaires administered at 12 and 30 months following the weight loss intervention, those individuals who increased low-fat dairy intake did not lose more weight during the trial but did maintain their weight post-trial. A cross-sectional study from Radavelli-Bagatini et al. [22] found that women (n=1456) ages 70 to 85 who consumed 1.5 or more servings of dairy foods per day had greater whole body lean mass (p=0.001) and appendicular skeletal muscle mass (p=0.002) than women consuming 1.5 or fewer servings per day both before and after multivariate adjustment for age, BMI, energy intake, physical activity, smoking, and alcohol consumption. There were no differences with body fat mass or BMI.

Yet, several more studies reported few or no differences on adiposity markers following interventions with dairy foods. A randomized controlled trial [14] assigned 65 women ages 18 to 49 with obesity to one of three hypocaloric diets: high-dairy (30 g low-fat cheese plus three glasses milk daily), low-dairy (30 g low-fat cheese plus one glass milk), or a control diet (30 g low-fat cheese) for 12 weeks and found no differences in body weight, BMI, HC, WC, WHR, or body composition measurements between the three groups. Bendtsen et al. [15•] compared hypocaloric high-dairy and low-dairy diets in 96 men and women who were either overweight or had obesity. At the end of the 24-week trial, there were no differences in weight, body composition, or WC between the two groups. Participants in the low-dairy group had a higher decrease in HC (p=0.003 after adjustments), but it was the only significant difference between the groups. Among 25 adults with obesity who regularly consumed less than 700 mg per day of calcium, following a high-dairy diet (4 servings per day) compared to a diet with 700 mg calcium from diet and 600 mg of calcium from supplements or a placebo for 21 weeks did not lead to any additional benefits for weight, BMI, or body composition [18]. Another trial comparing higher dairy intake (at least 711 mL per day of milk) with lower dairy intake (less than 238 mL per day of milk) as part of a hypocaloric dietary intervention over 12 weeks among 51 women with obesity found that baseline and end of intervention weight, fat mass, BMI, and WC did not differ between the two groups [20]. Finally, after forty-seven overweight adults were asked to consume either 1 L per day of diet cola, mineral water, cola, or an isocaloric serving of semi-skimmed milk for 6 months, total fat mass, total lean mass, and weight did not differ between the 4 beverage groups. Drinking regular cola did lead to higher visceral adipose tissue than the other drinks as well as greater relative accumulation of liver fat (p<0.05) and muscle fat (p<0.05) [13].

The two studies in this review that included an exercise component to their intervention found benefits of a dairy-rich intervention on fat mass loss and lean mass gain. Maltais et al. conducted a randomized controlled trial in 26 overweight men with sarcopenia and a BMI under 30 [16]. Participants completed 4 months of resistance exercise and consumed one of three isovolumetric and isocaloric postexercise shakes: control (rice milk), milk-based, and soy-based. While there were no differences in BMI measurements, the dairy group lost more fat mass and gained more muscle mass relative to fat mass (p< 0.05). Body weight increased in the soy group (p<0.05) [16]. A randomized controlled trial by Josse et al. [17] compared the impacts of three different diets—a high-protein/high-dairy diet (6–7 dairy servings per day), an adequate-protein/medium-dairy diet (3–4 dairy servings per day), and an adequate-protein/low-dairy diet (0–1 dairy servings per day) in 90 premenopausal overweight women or women with obesity for 16 weeks. Participants were asked to expend 250 kcal of energy in a workout session each day with 2 days per week of resistance exercise. There were no differences in total body mass decreases between the groups after the intervention. However, the high-dairy group lost more fat mass and gained more lean mass (p<0.05) over the 16 weeks compared to the other two groups. During weeks 8 to 16, the high-dairy group gained more lean mass than the medium- (p>0.05) and low-dairy groups (p<0.01). The medium-dairy group did not change their lean mass, and the low-dairy group lost lean mass (p<0.05). The high-dairy group also lost more trunk fat (p<0.005) and visceral adipose tissue volume (p<0.05) than the low-dairy group. The authors concluded that higher protein and dairy intakes led to "more favorable body composition changes in women characterized by greater total and visceral fat loss and lean mass gain" [16].

Table 2 Summary of studies assessing dairy intake with measures of satiety in adults

Author and reference	Type of study	Participants	Outcome measures	Intervention	Results
Dougkas et al. [23]	Randomized crossover trial	N= 32 males 32.1 ± 9.1 years (y); body mass index (BMI) 26.8 ± 1.6 kg/m^2	• Satiety measure-ments via visual analog scale (VAS) • Energy intake at ad libitum meal	Dairy snacks OR water was provided after a standardized breakfast consumed in the fasted state (and preceded by standardized dinner meal). Dairy snacks included isocaloric and isovolumetric amounts of milk, yogurt, or cheese. Ad libitum pasta lunch of pasta with tomato sauce offered 90 min after snack.	Yogurt suppressed hunger more than isoenergetic and isovolumetric servings of milk or cheese. All dairy snacks reduced appetite and energy intake at an ad libitum lunch compared to water.
Law et al. [24]	Randomized crossover trial	N=30 males and females 64.6 ± 2.4 y; BMI: 25.6 ± 2.5 kg/m^2	• Satiety measure-ments via VAS • Energy intake at ad libitum meal	Participants consumed 250 mL of 2% fat milk or soy beverage, 175 g of 2% Greek yogurt, or 30 g of cheddar cheese as part of an isocaloric (380 kcal) meal with bread and jam. Water alone was provided as a control. After 180 min, participants were provided an ad libitum rice and meatball meal.	Cheese and yogurt increased satiety (suppressed appetite and desire to eat) more than milk or a soy beverage. There were no differences in energy intake at the ad libitum meal.
Maersk et al. [25]	Randomized crossover trial	N=24 males and females 20 to 50 y; BMI: 28 to 36 kg/m^2	• Satiety measure-ments via VAS • Energy intake at ad libitum meal	Participants had 4 separate test days with a 2-week washout period between them. Participants consumed a standardized evening meal the night before and arrived fasted. Participants consumed 500 mL of test beverages (coke, semi skim milk, diet coke, mineral water)—interventions were unblinded. Four hours after the intervention, participants were provided with an ad libitum pizza lunch.	Compared to drinking cola, drinking milk led to greater subjective fullness and less hunger, and there were no significant differences in satiety, prospective intake, or energy intake at the ad libitum meal.
Ortinau et al. [26]	Randomized crossover trial	N= 20 females 27 ± 2 y; BMI: 23.4 ± 0.7 kg/m^2	• Satiety measure-ments via VAS • Energy intake at ad libitum meal	This study compared the satiating impact of isocaloric (160 kcal) snacks: high-protein yogurt, high-fat crackers, and high-fat chocolate. Participants consumed a standardized breakfast and lunch, then the assigned snack. An ad libitum "pizza pocket" dinner was provided when requested by participants.	Consuming yogurt led to greater reductions in hunger but no differences in fullness compared to chocolate. Yogurt also delayed eating initiation by 30 min compared to chocolate snack and decreased caloric consumption at dinner. Crackers also led to greater fullness at 90 min post-snack compared to the chocolate.
El Khou-ry et al. [27]	Randomized crossover trial	N=18 males 20 to 30y; BMI: 20 to 24.9 kg/m^2	• Satiety measure-ments via VAS • Energy intake at ad libitum meal	Participants consumed 250 g of one of five treatments (fat-free plain yogurt, fat-free plain yogurt with honey, fat-free strawberry yogurt, skim milk, orange juice) as mid-morning snacks after a standard breakfast. An ad libitum pizza meal was provided 120 minutes after.	There was no effect of these different treatments on measurements of satiety or food/energy intake.

Satiety

Five randomized crossover trials also assessed the impact of dairy intake (milk, yogurt, and/or cheese) on satiety, when compared to water, soy beverage, cola, diet cola, orange juice, crackers, and chocolate. These studies are summarized below and in Table 2.

When dairy foods were compared, in two separate randomized crossover trials, cheese and yogurt had greater appetite-suppressant impacts than either milk, water, or soy beverage, but there were no differences between the dairy foods on energy intake at subsequent ad libitum meals [23, 24]. In one trial [23], dairy snacks (isocaloric and isovolumetric amounts of milk, yogurt, and cheese) or water was provided to 32 overweight men after a standardized breakfast. VAS ratings of satiety (hunger, fullness, desire to eat, prospective food consumption) were assessed at regular intervals and energy intake was assessed with an ad libitum pasta lunch provided 90 min after the dairy snacks. All dairy snacks reduced appetite and energy intake at the ad libitum lunch compared to water, but yogurt had the greatest suppressant effect on appetite ratings overall, followed by cheese, milk, and water. Fullness was higher and prospective food consumption was lower after yogurt versus milk and water but was not different from cheese. Another trial [24] compared the satiety impacts of 2% milk, soy beverage, 2% Greek yogurt, or cheddar cheese consumed as part of an isocaloric (380 kcal) meal with bread and jam with water (served by itself) as a control. Participants completed VAS ratings of satiety at regular intervals and, after 180 min, were provided an ad libitum rice and meat sauce meal. Although there were no differences in food or energy intake at the ad libitum meal, all treatments led to higher fullness than water, and yogurt led to higher fullness than milk. Yogurt and cheese suppressed appetite and desire to eat more than milk and water and lowered appetite more than milk and soy beverage. Cheese reduced prospective food consumption compared with water and milk.

In a third randomized crossover trial, 20 young women with normal BMIs found that eating yogurt led to greater reductions in hunger but no differences in fullness compared to eating an isocaloric amount of chocolate [26]. In this study, eating yogurt also delayed eating by 30 min compared to chocolate and led to lower caloric consumption at a subsequent ad libitum meal [26]. Another randomized crossover trial had participants (n=24 adults who were overweight or had obesity) consume a standardized evening meal the night before the intervention, arrive fasted, and consume 500 mL of either a cola beverage, semi-skimmed milk, diet cola, or mineral water. Four hours after drinking the beverages, participants were provided an ad libitum pizza lunch. Satiety was assessed with VAS scales and energy intake was evaluated with the pizza lunch. Compared to drinking cola, drinking milk led to greater subjective fullness and less hunger, but there were no differences in energy intake between groups at the pizza meal, meaning that the energy from the caloric beverages was not compensated for at the subsequent meal [25]. Similarly, when compared to an isovolumetric amount of orange juice, fat-free yogurt (flavored with strawberry or honey) and skim milk consumed by 18 healthy young men did not have different impacts on either VAS satiety ratings or energy intake at an ad libitum pizza meal provided 120 min after the dairy and orange juice treatments [27].

Discussion

While the adiposity-focused studies in this review used different methods, their conclusions are similar. The four publications of randomized crossover trials compared the impacts of a high-dairy diet and a low-dairy diet and found few differences between the two dietary interventions on adiposity measures [8–11]. The randomized controlled trials and the single substudy of a randomized controlled trial echo these findings. Most of the studies reported no differences or minimal differences [13–15, 18, 20] between a dairy-rich intervention and control interventions, which included soft drinks, water, and "low-dairy" diets, on measures of adiposity.

Some studies focused on either weight loss or weight loss maintenance did find a benefit to including 3–5 servings of dairy foods or their nutrients (especially calcium and vitamin D) in weight loss diets compared to a placebo [12•] or soy milk [19]. Including dairy foods did also help participants in one study maintain their weight loss [21]. The two studies in this review that included exercise interventions also both found that the dairy or "high-dairy" groups had greater increases in lean mass gain and greater fat mass loss compared to other groups with non-dairy interventions or low-dairy interventions [16, 17]. While consuming dairy foods may not in itself offer benefits for body composition or weight loss, when paired with resistance exercise or a hypocaloric diet, consuming at least the amounts of dairy foods recommended by the DGA may help support weight loss, lean mass gain, fat mass loss, and weight maintenance. More research is needed on these topics, however, especially with more diverse cohorts. Most of these studies [8–15, 17–21, 23, 25] were conducted in individuals who were overweight or had obesity at baseline. Only four of the studies included in this review assessed the impacts of dairy intake in normal-weight individuals [22, 24, 26, 27]. This review does not include adequate information to assess the ability of dairy intake to prevent overweight or obesity.

Satiety, the postprandial state that inhibits hunger and further eating, influences food intake and, therefore, can affect weight status and maintenance [28, 29]. Most ratings of satiety rely on human participants to subjectively assess their own sensations of fullness and appetite using VAS. Energy intake at an ad libitum meal is also commonly used as a quantitative assessment of satiety. However, there is not a systematic way to pair this subjective and quantitative data together when the results do not align. For instance, in this review, when the satiating impacts of dairy foods were compared in two separate randomized crossover trials, cheese and yogurt had greater appetite-suppressant abilities than milk, water, or soy beverage. However, these differences did not extend to energy intake at subsequent ad libitum meals [23, 24]. While participants reported feeling less hungry after eating yogurt and cheese, this subjective reporting was not reflected in actual energy intake. Therefore, while the authors of these studies concluded that yogurt and cheese were more satiating than milk and other beverages, the data indicates a more complex relationship.

In addition, these studies on satiety assess the satiating properties of dairy foods relative to other foods, like water, soy beverage, cola, diet cola, crackers, chocolate, and orange juice, which makes it challenging to draw conclusions about how satiating milk, cheese, and yogurt are. Furthermore, dairy foods were not always compared to similar foods. In the two studies that found that cheese and yogurt exerted a greater impact on subjective satiety measures [23, 24], cheese and yogurt—a solid and a semi-solid food—were compared to beverages that did not necessarily have the same macronutrient profile either. More research is needed in this area that compares foods with more similar physical structures, as previous evidence in satiety research indicates that food form and the role of different foods in an eating occasion context have an impact on perceived satiety, as does macronutrient content [30–32].

Conclusions

Dairy foods do not appear to exert a unique role in weight loss or weight gain. While some previous studies have indicated a more straightforward relationship between consuming dairy foods and adiposity [33–35], the body of more recent research discussed in this review indicates that the relationship between dairy foods and adiposity remains incompletely understood. Dairy foods do not seem to increase adiposity in overweight adults and adults with obesity, and cheese and yogurt may be more satiating than milk. To apply the findings in this review in a clinical setting, clinicians could counsel their patients that while dairy foods provide important nutrients in recommended healthy dietary patterns, they do not appear to either increase weight gain or promote weight loss. Additionally, clinicians could share that, based on subjective measures, solid and semi-solid dairy foods like cheese and yogurt may be more satiating than liquid ones, like milk, as well as other beverages and less nutrient-dense foods.

Abbreviations BMI, Body mass index; DGA, Dietary Guidelines for Americans; HC, Hip circumference; VAS, Visual analog scale; WC, Waist circumference; WHR, Waist-to-hip ratio

Acknowledgement JMH was employed by National Dairy Council when this article was being written.

Compliance with Ethical Standards

Conflict of Interest At the time this article was written, JMH was an employee of National Dairy Council.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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