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Milk-Fat Intake and Differences in Abdominal Adiposity and BMI:
Evidence Based on 13,544 Randomly Selected Adults

Klarissa Rae Wilkinson

A thesis submitted to the faculty of
Brigham Young university
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

Milk-Fat Intake and Differences in Abdominal Adiposity and BMI: Evidence Based on 13,544 Randomly Selected Adults

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Master of Science

The primary objective of this study was to evaluate the relationship between milk-fat intake and obesity, particularly abdominal obesity, in 13,544 U.S. adults. A secondary objective was to determine the extent to which the association was influenced by multiple potential confounding variables. This cross-sectional study used data from the 2011–2016 National Health and Nutrition Examination Survey (NHANES). Level of milk-fat content regularly consumed was the exposure variable. Body mass index (BMI) and sagittal abdominal diameter (SAD), a measure of abdominal obesity, were the outcome variables. SAD correlates strongly with visceral fat, when measured by computed tomography, and has been shown to predict cardiometabolic disorders better than BMI. After controlling for age, gender, race, physical activity, sedentary behavior, alcohol habits, and cigarette use, significantly lower BMIs were associated with regular nonfat and full-fat milk consumption ($F = 4.1$, $P = 0.0063$). A significantly lower SAD was associated only with regular consumption of nonfat milk ($F = 5.0$, $P = 0.0019$). No significant differences were found between the other milk-fat groups or milk abstainers. In this nationally representative sample, only 19.6% of adults regularly consumed low-fat milk. In conclusion, regular nonfat milk intake was associated with lower levels of abdominal adiposity compared to consumption of higher levels of milk-fat.

Keywords: overweight, obesity, sagittal diameter, waist circumference, dairy, diet

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1. Introduction

Obesity is defined as a body mass index (BMI) of ≥ 30 kg/m² [1]. Over the past 25 years, the prevalence of obesity in the United States has increased dramatically. Results from the 2017–2018 National Health and Nutrition Examination Survey (NHANES) indicate that 42.4% of U.S. adults are obese, with 9.2% being severely obese [2]. This upward trend is not without consequences. A review of the health outcomes of obesity shows that as BMI increases, so does the risk of cardiovascular disease, type 2 diabetes, some forms of cancer, and other life-threatening disorders [3].

In some cases, however, health problems can arise even without an increase in BMI [4]. Visceral adiposity, or abdominal obesity, is an independent risk factor for these and other comorbidities [5-10]. The widely accepted cut-point for abdominal obesity is a waist circumference of ≥ 40 inches (100 cm) in men and ≥ 35 inches (88 cm) in women [11]. Using this definition, approximately 52% of U.S. adults have abdominal obesity, compared to the 42% when classified using BMI [12].

One approach to combat the threat of obesity is a healthy diet. Daily energy balance is a function of energy intake and energy expenditure. Tipping the scale towards a negative energy balance, which is needed for weight loss, is best accomplished by decreasing total daily energy intake [13]. Thus, a healthy diet promotes the consumption of a variety of foods that help one stay within energy needs [14].

Milk has been purported as part of a healthy diet because of its rich source of nutrients, calcium, and protein. The association between milk intake and weight regulation has been the topic of many recent publications [15-18]. Several meta-analyses conclude that milk and dairy consumption are associated with decreased risk of obesity [19-25]. A few systematic reviews

have found no difference [17,26,27], and one meta-analysis reports a positive correlation between milk intake and obesity [15].

When it comes to the effect of low-fat compared to high-fat milk on body weight, the literature appears mixed. A systematic review by Kratz et al. [28] determined that observational data suggest an inverse association between high-fat dairy intake and obesity risk but remarked that the evidence was not conclusive. Of the 16 studies they reviewed, ten compared high-fat dairy to low-fat dairy. All ten reported an inverse relationship between high-fat dairy consumption and obesity measures, while low-fat had either a positive correlation or no relationship. Only one of these investigations looked at milk specifically, and showed that skim and 1% milk, not whole, were positively associated with an increase of BMI in children. It appears that no randomized controlled trials have evaluated low- and high-fat milk consumption and their effects on obesity in adults.

To date, few if any studies have explored the effect of milk-fat on abdominal obesity as opposed to general obesity. A 24-week randomized controlled trial by Zemel et al. [29] found that dairy intake resulted in greater total fat loss and fat loss in the trunk region than a control group with normal calorie restriction, but the fat content of milk was not considered. A significant amount of visceral or abdominal fat may pose greater risks than excess body weight and thus needs to be explored in conjunction with low- versus high-fat milk consumption [4-10].

The present study focused on determining the relationship between milk-fat intake and obesity, particularly abdominal adiposity, in 13,544 U.S. adults. Additionally, the influence of age, gender, race, physical activity, recreational computer use (physical inactivity), cigarette smoking, and alcohol use on the milk and obesity relationships were investigated.

2. Materials and Methods

2.1. Study Design and Sample

This cross-sectional study used data from the National Health and Nutrition Examination Survey (NHANES). NHANES is a major component of the National Center for Health Statistics which is a part of the Centers for Disease Control and Prevention. To collect data, NHANES conducts comprehensive interviews and physical examinations on nationally representative samples.

Prior to data collection, written informed consent was obtained from each participant. Data collection was approved by the Ethics Review Board for the National Center for Health Statistics and files were allowed to be posted on the NHANES website for public use [30]. On their website, NHANES provides a full description of data collection methods and procedures [31]. The present study utilized NHANES data collected from 2011–2016. The ethical approval code for NHANES data collection 2011–2016 is: Protocol #2011–17.

The current investigation consisted of a total of 13,544 participants, ages 20–79 years. Data were collected using a four-stage random sampling of noninstitutionalized U.S. adults. NHANES uses census data to select counties, blocks, dwelling units, and finally persons, selecting subsamples from each, in order for the data to be nationally representative [31].

2.2. Instrumentation and Measurement Methods

In the present investigation, the exposure variable was milk consumption, indexed according to milk-fat content. There were two outcome measures: body mass index (BMI) and sagittal abdominal diameter (SAD), a measure of visceral adiposity. Age, sex, race, physical activity and inactivity levels, cigarette smoking, and alcohol use were included as covariates to control for their influence on the relationship between the exposure and outcome variables.

2.2.1. Milk Consumption

Milk consumption was measured using the NHANES Diet Behavior and Nutrition questionnaire [32]. Subjects were questioned about their milk consumption over the previous 30 days. The NHANES examiner asked, “Now I’m going to ask a few questions about milk products. Do not include their use in cooking. In the past 30 days, how often did you have milk to drink or on your cereal? Please include chocolate and other flavored milks as well as hot cocoa made with milk. Do not count small amounts of milk added to coffee or tea.” Participants were able to answer: Never; Rarely (less than once a week); Sometimes (once a week or more, but less than once a day); Often (once a day or more); or Varied [32]. Participants who reported that their milk intake varied were not included in the study (n = 47).

Subjects were also divided by the type of milk they reported drinking. The question was asked, “What type of milk was it? Was it usually...?” Subjects answered whole milk; 2% fat milk; 1% fat milk; fat-free or skim milk; soy milk; or other. Milk-fat percentage refers to the proportion of milk, by weight, that consists of butterfat. Regular milk drinkers were defined as someone who consumed any type of milk at least five times a week. Participants who reported that they solely drank soy milk (n = 82) or another type other than cow’s milk (n = 229) were not included in the analyses [32].

2.2.2. Body Mass Index

Body mass index (BMI) is an indicator of body weight independent of height. It was one of the two outcome measures, as it is frequently used as a measure of overweight and obesity. BMI is calculated as weight in kilograms divided by the square of height in meters. BMIs less than 18.5 classify a subject as underweight. Normal weight BMIs are 18.5–24.9 kg/m². A BMI of 25–29.9 is considered overweight, and BMIs of 30 or greater are classified as obese [33].

Participants with extreme BMIs (>3 standard deviations above the mean: >50.6 kg/m²) were not included in the analyses (n = 184).

2.2.3. Sagittal Abdominal Diameter

Sagittal abdominal diameter (SAD) was used as a measure of visceral adiposity in the present study. SAD is an index of abdominal height [34]. It was measured with the subject in the supine position on an examination table. Knees were bent at a 90-degree angle with hands resting on the chest and feet flat on the table. The NHANES examiner located the uppermost lateral border of the right and left ilium, making a 5 cm mark on the abdomen along the iliac level line. An abdominal caliper was then used to measure the distance in centimeters between the small of the back and the abdominal mark. This measurement was taken at least two times to ensure accuracy. SAD has previously been shown to predict cardiometabolic disorders better than BMI and waist circumference [35-37], and correlates strongly with visceral fat as measured by computed tomography [38].

2.3. Covariates

NHANES classifies race into five categories: Mexican American, Non-Hispanic Black, Non-Hispanic White, Other Hispanic, and Other Race. The NHANES racial categories were used in the present study.

A stadiometer was used to measure standing height [34]. Subjects stood up straight with their body weight evenly distributed, heels together, and feet pointing slightly outward. Head, shoulder blades, buttocks, and heels were in contact with the stadiometer backboard when height was taken. Weight was assessed in kilograms using a digital weight scale [34]. Each day, the scale was calibrated with a calibration weight. Participants stood on the center of the scale with

hands at sides. The only clothing worn by subjects was underwear, disposable shirt and pants, and slippers, which were provided to them [34].

Physical activity (PA) levels were also measured via interview. As PA increases, energy expenditure increases [39]. Physically active people tend to weigh less and have less abdominal obesity than inactive people [40]. Hence, PA was used as a covariate in the present study. In the interviews, subjects were asked about the amount of time spent in moderate and vigorous physical activity. Moderate PA was defined as activity that causes small increases in breathing or heart rate, such as carrying light loads or brisk walking. Vigorous PA was defined as activity that causes large increases in breathing or heart rate, such as lifting heavy loads or jogging [41].

Specifically, an NHANES examiner asked, “In a typical week, on how many days do you do moderate-intensity sports, fitness, or recreational activities? “How much time do you spend doing moderate-intensity sports, fitness, or recreational activities on a typical day?” The same questions were asked for vigorous-intensity PA. For each intensity, days and minutes were multiplied together to calculate total minutes of moderate and total minutes of vigorous PA. These minutes were then added together, resulting in total moderate and vigorous PA (MVPA).

Physical inactivity, on the other hand, leads to a decrease in total daily energy expenditure [39]. As such, it has been shown to be a risk factor for obesity and abdominal obesity in correlational and causative studies [42,43]. In today’s society, recreational computer use and gaming are often part of a sedentary lifestyle [44,45]. Therefore, subjects’ recreational computer use was measured via questionnaire in the current investigation. Information was gathered about computer and portable game usage, not associated with work or school, over the past 30 days. Subjects responded with no recreational computer use, less than one-hour use per day, one hour, two hours, three hours, four hours, five or more hours, or do not know. Subjects

who indicated more than zero and less than one-hour per day were assigned 0.5 hour per day of use. The highest two use categories were combined into one category, four hours or more per day.

Cigarette smokers are less likely to be obese than nonsmokers, hence smoking was used as another covariate in the present investigation [46-48]. Smoking was indexed using the average number of cigarettes smoked per day during the past 30 days. An NHANES examiner asked, “During the past 30 days, on the days that you smoked, about how many cigarettes did you smoke?” Possible responses were any range of values from one to 95 [41].

Alcohol use was included as the final covariate in the current study. NHANES divides alcohol use into three categories by gender. Women who had two or more alcoholic drinks per day or men who had three or more were considered heavy drinkers. Women who consumed >0 to <2 alcoholic drinks per day or men who consumed >0 to <3 drinks were considered moderate drinkers. Those who did not drink alcohol were categorized as abstainers. Alcohol use has been shown to be a risk factor for obesity [49].

2.4. Data Analysis

In the present investigation, strata, clusters, and individual sample weights were employed in the analyses so the results can be generalized to all civilian, noninstitutionalized adults in the United States. Although a sample size of 13,544 adults would usually result in substantial statistical power, NHANES use of a multilevel sampling strategy reduced power significantly. Specifically, instead of approximately 13,544 degrees of freedom (df), because of nesting, degrees of freedom in the denominator was computed as the number of clusters minus the number of strata, which resulted in 47 df.

There was one exposure variable in the analyses: the fat content of the milk consumed. There were two outcome variables: BMI and the sagittal abdominal diameter (SAD). A number of covariates were controlled statistically to reduce their influence on the relationship between the exposure variables and the outcome measure, specifically age, sex, race, physical activity, physical inactivity, cigarette smoking, and alcohol use.

The two outcome variables, BMI and SAD, were treated as continuous variables. The exposure variable, the milk-fat content regularly consumed by participants, was treated as a categorical variable. One-way analysis of variance (ANOVA) was used employing the SAS SurveyReg procedure to determine mean BMI or SAD differences across the milk-fat categories. Potential mediating variables were controlled using partial correlation, and the Least Squares Means (LSMeans) procedure was employed to generate adjusted means.

SAS version 9.4 (SAS Institute, Inc., Cary, NC) was the software utilized to analyze the data. All of the analyses were two-sided and alpha was set at <0.05 for statistical significance.

3. Results

Participants were randomly selected, and sample weights were used so the results are generalizable to the civilian, noninstitutionalized U.S. adult population. A total of 6,743 men and 6,801 women were included in the study (n = 13,544). The average (\pm SE) age of the sample was 46.3 (\pm 0.3) years. Table 1 displays the categorical variables of the study. Milk abstainers comprised 39.6% of the sample, 27.9% reported they drank milk sometimes, and 32.5% reported they drank milk often. The most commonly consumed milk was 2% milk-fat (25.8%), followed by full-fat milk (15.0%). Sedentary behavior was quantified using hours of recreational computer use. Computer use for school or work was not counted. A majority of subjects reported 0.5 hours per week or less, and about 30% indicated they participated in 2 hours or more of recreational

computer use. The percentage of the sample that were alcohol abstainers, moderate drinkers, or heavy drinkers was relatively equal.

Table 1. Descriptive characteristics of the sample (n = 13,544).

Variable	N	Weighted %	SE
Gender			
Men	6743	49.7	0.4
Women	6801	50.3	0.4
Race			
Mexican American	1957	9.0	1.2
Other Hispanic	1497	6.3	0.8
Non-Hispanic White	4893	65.1	2.2
Non-Hispanic Black	3060	11.2	1.2
Other Race	2137	8.4	0.6
Sedentary Behavior[‡]			
0 hours/week	4134	22.4	1.0
0.5 hours/week	3283	28.3	0.7
1 hours/week	2259	19.6	0.6
2 hours/week	1736	13.9	0.4
3 hours/week	815	6.1	0.3
4 or more hours/week	1314	9.7	0.4
Alcohol Use			
Abstainer	5089	30.3	0.9
Moderate Drinker	4047	33.3	0.9
Heavy Drinker	4408	36.4	0.7
Milk Intake Frequency[*]			
Never/Rarely	5534	39.6	0.8
Sometimes	3816	27.9	0.6
Often	4194	32.5	0.7
Milk-Fat Consumed			
Milk Abstainers	5547	39.6	0.7
Full-Fat	2435	15.0	1.4
2% Milk	3588	25.8	1.3
1% Milk	1025	9.2	1.1
Nonfat Milk	949	10.4	1.2

*For the Milk Intake Frequency variable, adults reporting “Never/Rarely” consumed milk < once per week; “Sometimes” was > once per week, but < once per day; and “Often” consumed milk at least once per day.

[‡]Hours of recreational computer use were used to index sedentary behavior. The Weighted % column shows the distribution of subjects after the NHANES sample weights were applied. The Weighted % values are more meaningful than the number of subjects because they consider the sample weights and reflect the percentage of the U.S. population that practice the behavior. SE is standard error of the weighted percentage.

The average (\pm SE) BMI of the subjects was 29.1 (\pm 0.1) kg/m², and the average sagittal abdominal diameter (SAD) was 22.7 (\pm 0.1) cm. In the sample, 40% of subjects accumulated zero

minutes of moderate to vigorous physical activity (MVPA) per week, with the mean (\pm SE) being 162 (\pm 5) minutes per week. Additionally, for the less than 20% of the NHANES sample that smoked, average (\pm SE) number of cigarettes each month was 69.9 (\pm 3.7).

Table 2 displays the percentiles associated with the continuous variables of the study. The median value for BMI was 28.0 (\pm 0.1) kg/m² and the median for SAD was 22.2 (\pm 0.1) cm. Median minutes of MVPA per week was 56.6 (\pm 7.4). The median number of cigarettes smoked over a 30-day period was 0 (\pm 3.3) since most of the population were nonsmokers.

Table 2. Percentiles for the continuous variables.

Variable	Percentile (\pm SE)				
	5 th	25 th	50 th	75 th	95 th
BMI (kg/m ²)	20.6 \pm 0.1	24.4 \pm 0.1	28.0 \pm 0.1	32.6 \pm 0.2	41.4 \pm 0.3
Sagittal Diameter (cm)	16.5 \pm 0.1	19.4 \pm 0.1	22.2 \pm 0.1	25.5 \pm 0.1	30.5 \pm 0.2
Smoking (cigarettes/30 days)	0 \pm 3.3	0 \pm 3.3	0 \pm 3.3	0 \pm 3.3	582.5 \pm 36.0
MVPA (minutes/week)	0 \pm 8.3	0 \pm 8.3	56.6 \pm 7.4	236.4 \pm 8.2	680.7 \pm 27.6

SE: standard error. A sample weight was included with each statistical analysis, so the results represent the U.S. adult population. Smoking was indexed as the number of cigarettes smoked per 30 days. MVPA was the combined minutes of moderate and vigorous physical activity per week. Less than 20% of the sample smoked, hence no number is reported until the 95th percentile. Similarly, adults in the 5th and 25th percentiles for MVPA accumulated less than 10 minutes of MVPA per week.

Table 3 compares the BMI and SAD means according to milk-fat intake. Model 1 controlled for the demographic covariates only (age, gender and race). Milk abstainers and those who drank 1% or 2% had statistically equal BMIs, whereas subjects who drank nonfat or full-fat milk had significantly lower BMIs than the other groups ($F = 4.5$, $P = 0.0037$). The difference in BMI between nonfat or full-fat milk drinkers was not statistically significant.

Milk-fat intake associated with SAD outcomes were different than for BMI. Specifically, the smallest average SAD was seen in nonfat milk drinkers. There was no difference in SAD between adults who consumed full-fat milk, 2%, 1%, or milk abstainers. However, adults who drank nonfat milk had significantly smaller mean sagittal abdominal diameters than each of the other milk-fat groups and milk abstainers ($F = 5.6$, $P = 0.0009$).

Model 2 in Table 3 controlled for the demographic and lifestyle covariates: age, gender, race, physical activity, sedentary behavior, alcohol habits, and cigarette use. Similar to Model 1, statistically equal mean BMIs were seen in milk abstainers, those who drank 1%, and those who consumed 2% milk-fat. Drinking nonfat or full-fat milk compared to 1%, 2%, or abstaining from milk was associated with significantly lower BMIs ($F = 4.1$, $P = 0.0063$).

According to Model 2, with all the covariates controlled, mean SAD was smaller in nonfat milk drinkers compared to each of the other milk groups: 1%, 2%, full-fat, and also milk abstainers ($F = 5.0$, $P = 0.0019$). Although nonfat milk consumers had significantly smaller sagittal diameters, the other milk groups did not differ significantly from each other.

Table 3. Differences in mean (\pm SE) BMI or sagittal abdominal diameter by milk-fat content consumed by U.S. adults, after adjusting for the covariates.

Model:	Milk-Fat Content Typically Consumed					F	P
	Milk Abstainer Mean \pm SE	Full-Fat Mean \pm SE	2% Mean \pm SE	1% Mean \pm SE	Nonfat Mean \pm SE		
Model 1							
BMI	29.3 \pm 0.1 ^b	28.4 \pm 0.3 ^a	29.4 \pm 0.2 ^b	29.5 \pm 0.3 ^b	28.4 \pm 0.4 ^a	4.5	0.0037
SAD	22.8 \pm 0.1 ^b	22.5 \pm 0.2 ^b	23.0 \pm 0.2 ^b	22.9 \pm 0.2 ^b	21.9 \pm 0.2 ^a	5.6	0.0009
Model 2							
BMI	29.3 \pm 0.1 ^b	28.5 \pm 0.3 ^a	29.3 \pm 0.2 ^b	29.3 \pm 0.3 ^b	28.3 \pm 0.4 ^a	4.1	0.0063
SAD	22.7 \pm 0.1 ^b	22.6 \pm 0.2 ^b	23.0 \pm 0.2 ^b	22.9 \pm 0.2 ^b	22.0 \pm 0.2 ^a	5.0	0.0019

BMI was used as a measure of weight independent of height. SAD was used as an index of abdominal adiposity. ^{a,b} Means on the same row with the same superscript letter are not statistically different ($P > 0.05$). Levels of milk-fat intake were defined as follows—Milk Abstainer: subjects who never consumed milk ($n = 5541$, 57.0%); Full-fat: participants who usually consumed whole or full-fat milk. ($n = 1219$, 12.5%); 2%: individuals who typically consumed 2% milk ($n = 1857$, 19.1%); 1%: adults who usually consumed 1% milk ($n = 540$, 5.6%); Nonfat: participants who typically consumed nonfat, skim, or 0.5% milk ($n = 571$, 5.9%). When summed, percentages may not equal 100% because of rounding. Participants who reported drinking milk “sometimes” were not included in the analysis. SE is standard error of the mean. Model 1 compares BMI and SAD means separately, after controlling for the demographic covariates (age, gender, and race). Model 2 compares BMI and SAD means separately, after adjusting for the demographic and lifestyle (age, gender, race, physical activity, sedentary behavior, alcohol habits, and cigarette use) covariates. The NHANES sample weights assigned to each subject are not reflected in the number of participants in each category (n). However, the sample weight is applied to the percentage (%) following the sample size. Therefore, the percentage is a more meaningful value.

4. Discussion

The objective of this study was to assess the relationship between milk-fat intake and obesity. General obesity was measured using BMI and abdominal obesity, the primary focus of the study, was measured by SAD (sagittal abdominal diameter). The results were derived using a random sample of 13,544 U.S. adults as part of the National Health and Nutrition Examination Survey (NHANES). A secondary aim was to determine the extent to which a number of demographic and lifestyle covariates influenced the relationship between milk-fat intake, obesity, and abdominal adiposity.

This study resulted in several meaningful findings. First, adults who regularly drank either nonfat or full-fat milk had significantly lower BMIs than adults who drank 1% or 2% milk or abstained from drinking milk. However, when the relationship between milk-fat intake and SAD was evaluated, only nonfat milk drinkers had significantly lower SADs compared to the other milk-fat groups. These results remained significant after controlling for potential confounding factors.

Results of the present study support the current Dietary Guidelines for Americans (2015–2020) [50], which encourage adults to consume low-fat milk, rather than high-fat milk. The Guidelines define low-fat milk as nonfat milk or 1%. Given the lower prevalence of abdominal adiposity in nonfat milk consumers compared to adults who drink 1%, milk drinkers should probably consume nonfat milk, rather than 1%, even though both are labeled low-fat.

According to Table 1, a total of 19.6% of adults consume low-fat milk. Only 10.4% drink nonfat milk. The percentage of adults who drink high-fat milk (2% and full-fat) is 40.8%, and 39.6% are not regular milk drinkers. It appears that a large number of U.S. adults regularly

consume high-fat milk, which is discouraged by the U.S. Dietary Guidelines [50] and is associated with increased abdominal fat (SAD) in the current study.

Other studies have shown similar relationships between low-fat milk intake and BMI [51-53]. For example, an eight-week randomized crossover trial by Alonso et al. [54] compared the addition of either low-fat dairy or high-fat dairy to young adults' diets. They found that the inclusion of high-fat dairy significantly increased body weight compared to low-fat dairy.

Faghih et al. [55] randomized 100 premenopausal women to one of the following regimens for eight weeks, all of which included a deficit of 500 kcal/day: 1) 500–600 mg/day dietary calcium, 2) 800 mg/day calcium supplement, 3) three servings/day of low-fat milk, or 4) three servings/day of soy-milk. Weight reductions in low-fat milk, soy milk, calcium supplement and control groups were 4.4 ± 1.9 kg, 3.5 ± 1.3 kg, 3.9 ± 2.4 kg and 2.9 ± 1.6 kg, respectively. The authors concluded that increasing low-fat milk intake reduced weight and waist circumference beyond an energy-restricted diet.

A randomized controlled trial by Rossi et al. [56] treated 40 obese women for 12 weeks. Participants were given iso-caloric diets, with one group consuming no dairy and the other consuming two servings of low-fat dairy per day. After 12 weeks, subjects in the no dairy group lost 6.0% body fat and subjects in the dairy group lost 10.8% body fat ($p < 0.01$). No significant difference was seen in waist circumference or visceral fat in either group, beyond the effects from a low-calorie diet.

Conversely, there are some studies that support high-fat milk intake and lower BMI. A cross-sectional study by Crichton et al. [57] found high-fat milk consumption to be inversely related to BMI and waist circumference after having 1,352 adults complete a food frequency

questionnaire. Participants in the highest tertile of high-fat milk intake had significantly lower odds for general obesity and abdominal obesity, compared with those in the lowest tertile.

A cohort study by Holmberg et al. [58] studied 1,589 Swedish men. Waist and hip circumferences were measured, and dietary analyses were completed at the beginning and end of a 12-year follow-up period. The researchers found that a high intake of high-fat milk was inversely related to risk of abdominal obesity (OR 0.52, 95% CI: 0.33–0.83) compared to a medium intake. Other studies have shown similar findings [28,59-62].

Studies that have investigated the relationship between low-fat milk intake and abdominal obesity report results similar to the current investigation [63,64]. A cross-sectional study by Ardekani et al. [65] compared low-fat milk intake to high-fat milk intake in 8,652 Iranian adults and found that adults who drank low-fat milk had significantly lower body fat percentages and abdominal obesity than the high-fat milk drinkers. Additionally, self-reported low-fat milk intake was associated with a lower waist-to-hip circumference in a study by Krachler et al. [66]. However, none of the above studies included SAD as a variable.

Why did results for BMI and SAD differ in the present study? Perhaps it is because BMI is a general index of body weight for a given height, whereas SAD is a sensitive measure of adiposity, particularly abdominal fat. BMI does not differentiate between lean mass and fat. However, SAD correlates strongly with visceral fat, when measured by computed tomography [38]. Furthermore, SAD correlates with an increased risk of disease [4-10], even if general obesity is not present. Elevated levels of visceral fat seem to pose a greater risk than excess body weight alone [52,67,68]. Consequently, SAD provides more valuable information than BMI.

Several potential mechanisms could explain the inverse relationship found between nonfat milk intake and SAD in the current study. High-fat milk has a higher caloric content

compared to low-fat milk. A diet with an excess of calories is known to increase fat stores in the body [13]. Additionally, individuals often do not compensate for the consumption of liquid calories, which could result in excess intake of energy [69,70]. Similar findings have been reported in children [71]. Moreover, it is possible that adults who regularly drink low-fat milk are more health conscious in other areas of their diet and consequently select foods that are lower in calories compared to high-fat milk drinkers. There could exist other variances in subjects' lifestyles, not including physical activity, smoking, and alcohol use, which were controlled in the present study.

Some limitations exist in the current study. First, conclusions about the present study must be made carefully, as it was a cross-sectional study. Cross-sectional studies cannot control for all possible confounding factors; thus, causation cannot be concluded. Statistical adjustments were made for differences in demographic and lifestyle variables at the analysis level of this study. Additionally, data on milk-fat intake were self-reported, which could result in misclassifications. The present study warrants further investigation in this area.

The present study has several strengths. First, multiple races and a large, randomly selected sample ($n = 13,544$) were included in the study. This makes the findings generalizable to the U.S. noninstitutionalized, civilian adult population. Second, SAD was used as a measure of abdominal adiposity, which is not a usual measurement in the literature but correlates strongly with visceral adiposity. Third, the association between low-fat milk intake and lower levels of SAD were consistent and highly significant. Fourth, several demographic and lifestyle variables were controlled statistically, reducing their impact on the relationship between milk-fat intake, BMI, and SAD. Fifth, this study sheds light on the difference between low-fat and high-fat milk

intake in relation to abdominal adiposity, particularly SAD, which is not common among milk and dairy investigations.

5. Conclusions

The literature surrounding milk-fat intake and obesity in adults is mixed and the topic controversial. In the current study, both overall obesity and abdominal adiposity were assessed. Sagittal abdominal diameter (SAD) is an excellent measure of abdominal adiposity, whereas BMI is a general index of body weight for height. SAD also seems to be a better predictor of disease risk than BMI. Both nonfat and full-fat milk intake were associated with a lower BMI. However, only nonfat milk consumption was related with a lower SAD; high-fat milk intake was not. The present investigation highlights the potential advantage associated with U.S. adults consuming low-fat milk. The findings support the current Dietary Guidelines for Americans (2015–2020) which encourage consumption of low-fat milk as part of a healthy diet.

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Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data supporting reported results can be found online as part of the National Health and Nutrition Examination Survey (NHANES). The data are free and can be found at the following website: <https://wwwn.cdc.gov/nchs/nhanes/Default.aspx>

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