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Dairy Intake, Obesity, and Metabolic Health in Children and Adolescents: Knowledge and Gaps

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There is an urgent need to identify nutrition-related risk factors for obesity and the metabolic syndrome, because the prevalence of these conditions continues to rise among children and adolescents. While some studies suggest that dairy and calcium intake may attenuate obesity and the metabolic syndrome, others do not support these findings. In addition, very little research has been done in children and adolescents, especially in minority youth, who are at the greatest risk for obesity and metabolic dysfunctions. Longitudinal studies examining the role of dairy intake in relation to changes in body composition and metabolic profiles during growth are also critically needed. Of the studies conducted thus far, part of the discrepancy in findings may be due to the uncertainty over whether the effect of dairy intake is independent of energy intake or other eating pattern variables. Further, there is no consensus on how to qualify (i.e., which foods) or quantify (i.e., which cutoffs and/or units) dairy consumption. The widespread problem of implausible dietary reporting in observational studies and the lack of compliance monitoring in intervention trials may also contribute to inconsistent findings. Given the lack of consensus on the effect of dairy, particularly in children and adolescents, more research is warranted before any recommendations can be made on dietary guidelines, policies, and interventions.

Key words: dairy, calcium, obesity, metabolic syndrome, children, adolescents

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Introduction

As the obesity epidemic increasingly becomes a major health threat in the United States and around the world, there is an urgent need to identify modifiable dietary risk factors for obesity and obesity-related disorders. The intake of dairy, an easily accessible and nutrient-rich food group as well as the major source of dietary calcium in the United States, has been proposed as one such potential factor. While some studies have suggested a protective effect of dairy intake against obesity and the metabolic syndrome (i.e., a cluster of metabolic dysfunctions including central obesity, hypertension, low-HDL cholesterol, hypertriacylglycerolemia, proinflammatory state, and insulin resistance/glucose intolerance), results have been very inconsistent across studies, and few studies have examined the effect of dairy intake in children and adolescents, particularly with regard to growth-related changes in body composition and metabolic profiles. In addition, questions remain as to the mechanisms by which dairy exerts its potentially protective effects. Some recent adult studies have suggested that dairy may play a role in the biological modulation of blood pressure and lipid and sugar metabolism, but these effects may be dependent on total energy intake. Moreover, some studies have suggested an augmented anti-obesity effect with the intake of whole dairy foods compared with dietary calcium alone. These findings, however, are not conclusive and are even less so in children and adolescents than in adults. Inconsistent definitions of dairy consumption and health outcomes, the widespread problem of obtaining dietary reports inconsistent with energy needs, and the lack of compliance monitoring during interventions may have contributed to discrepant findings among studies.

Prevalence of Obesity and Dairy Intake

The prevalence of obesity in children and adolescents has increased dramatically in recent years, with 16.5% of children and adolescents aged 6 to 19 years of age now classified as overweight (BMI $\geq$ 95th percentile).[1] In addition, over 20% of overweight children show symptoms of the metabolic syndrome.[2,3] The epidemic of childhood obesity has been proposed to be due in part to rapid changes in diet and physical activity patterns, including a decrease in the consumption of dairy, concurrent with an increase in the consumption of sweetened beverages.[4-7] The concomitant increase in childhood obesity and decrease in dairy, particularly milk, intake have led researchers to hypothesize that the two may be etiologically related.

The mean intake of dairy among US children and adolescents is approximately two servings (16 fl. oz. of milk) per day, the minimum recommended intake for this food group based on the US Food Guide Pyramid.[4] This suggests that a great majority of children and adolescents do not meet the minimum recommendation. Using the Nationwide Food Consumption Survey and the Continuing Survey of Food Intakes by Individuals, secular analysis of milk intake among adolescents showed a decrease of 36% or half a serving (i.e., 4 fl. oz.) from 1965 to 1996,[8] indicating that in 1996, US adolescents were meeting only 74% of the recommended calcium intake. The decrease in milk consumption over time was mostly due to a decrease in whole and medium-fat milk intake, while absolute intake of low-fat milk has remained fairly stable since 1977.[8] Note, however, that low-fat milk intake as a percentage of total energy intake decreased significantly in children and adolescents from 1977 to 1996.[9]

Other large surveys corroborate the above findings. For instance, in the Bogalusa Heart Study,[10] it was shown that the mean intake of milk in grams decreased significantly in 10-year-old children from 1973 to 1994, while cheese consumption increased. The increase in cheese consumption was only 18 g compared with a decrease of 64 g in milk consumption, resulting in a significant decrease of overall dairy consumption.[10] Among these children, 69% did not meet the dietary recommendation of 1300 mg of calcium a day. Other studies have shown similar trends.[11,12]

Milk Versus Sodas and Fruit Juices: The Role of Energy Intake

The decrease in milk consumption has been met with a dramatic increase in the consumption of caloric sodas and fruit-flavored beverages among US children and adolescents. From 1965 to 1996, the intake of caloric sodas and fruit-flavored drinks at least doubled in 11- to 18-year-olds (Figure 1).[8] Similarly, the proportion of children consuming sodas daily tripled over 5 years in those followed prospectively from grade 3 to grade 8.[13] This phenomenon may in part be responsible for the hypothesized inverse relationship between dairy intake and obesity.[4,8,14-16] Although it remains inconclusive, there is some evidence suggesting that the disproportionate rise in the consumption of high-sugar beverages might have contributed to an increase in overall energy consumption[9,17] and, hence, obesity.[18]

During 1994 to 1998, the mean intake of sodas was 2.9 fl. oz. per day among children 6 months to 6 years of age, and 12.4 fl. oz. a day among those 7 to 18 years of age.[19] In the same time period, the mean intake of fruit-flavored drinks and ades (excluding 100% fruit juices) was 4.0 fl. oz. per day among children 6 months to 6 years of age and 5.1 fl. oz. per day among those 7 to

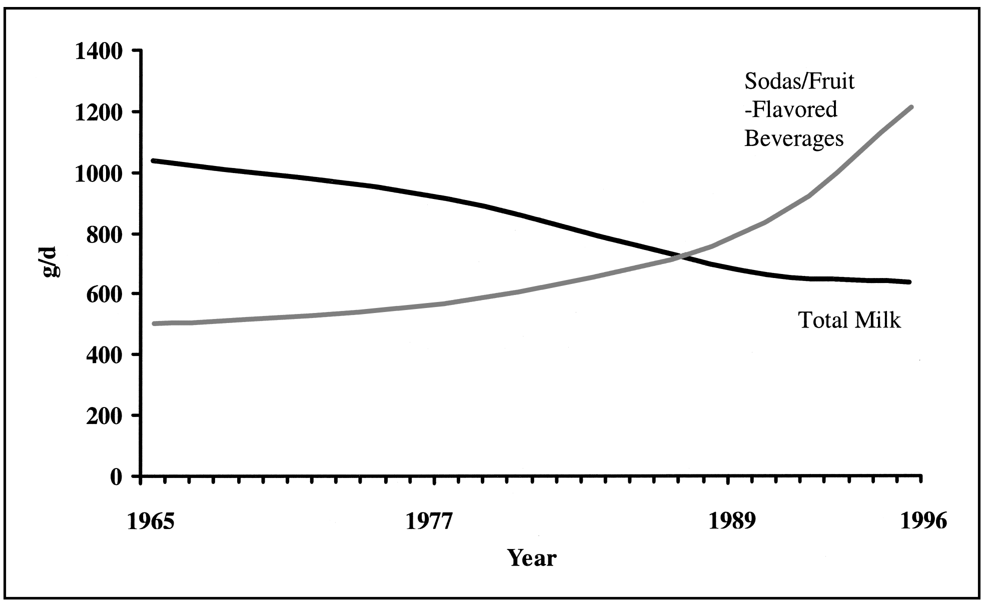

Figure 1. Trends of milk versus soda and fruit-flavored beverage consumption among US adolescents 11 to 18 years of age between the years 1965 to 1996. Graph is based on data from the Nationwide Food Consumption Survey and the Continuing Survey of Food Intakes by Individuals compiled by Cavadini et al.[8] 8 fl. oz. = 240 g.

18 years of age.[19] Therefore, among those 7 to 18 years of age, the combined intake of sodas and fruit-flavored beverages amounted to 17.5 fl. oz. per day, or more than two milk-equivalent servings in volume per day. Frary et al.[4] found that dairy intake was inversely related to the consumption of sugar-sweetened beverages in a national sample of children and adolescents. Thus, the increasing intake of high-sugar and nutrient-poor beverages relative to the modest decrease in milk intake may have resulted in a significant net increase in overall energy consumption, predisposing children and adolescents to an increased risk for obesity.

In addition to the overall high consumption of sodas over the years, the relatively higher energy density and greater serving size of sodas may have also contributed to increased obesity risk. For instance, a common, single-serving size (8 fl. oz.) of fat-free milk provides 83 kcal, whereas the same volume of regular, non-diet cola provides 104 kcal.[20] In addition, while 8 fl. oz. of 1% fat milk and regular cola contain about the same number of calories, and 8 fl. oz. of 2% fat milk contains 18 kcal more, individual-sized servings of cola normally come in larger volumes than this.[20] Indeed, a common can (12 fl. oz.) of regular, non-diet cola has 155 kcal. In fast-food restaurants, servings of regular cola often come in volumes of 16 fl. oz. (small, 207 kcal), 22 fl. oz. (medium, 284 kcal), 32 fl. oz. (large, 413 kcal), or 44 fl. oz (extra large, 568 kcal).[20] A typical single serving of regular cola has increased in size from 12 fl. oz. in the 1950s to 20 fl. oz. in 2000.[21] Portion size has been shown to be positively related to obesity in children and adolescents,[22] presumably because, at least in the short term, it leads to increased overall energy intake.[23] Thus, the difference in energy consumption and the ensuing health effects due to the replacement of dairy with sodas could theoretically be dramatic over time. Although different soda drinks have a slightly different per-unit caloric content, similar shifts in serving sizes and overall consumption are present among soda beverages other than cola.[24]

While more research is certainly warranted, three energy-dependent effects are hypothesized to occur when milk is replaced with sodas and nutrient-sparse fruit juices[15]: 1) as discussed above, increasing energy intake due to both higher calories per common serving and larger typical serving sizes of sodas and fruit juices compared with milk; 2) increasing other food intake, hence overall energy intake, due to decreased satiety with high-sugar beverages (in support of this, one recent study in adolescents found that compared with caffeinated or non-caffeinated sodas, low-fat milk intake yielded lower post-prandial glucose, insulin, and free-fatty acid responses, as well as lower scores of hunger and desire to eat[25]); or 3) lower energy expenditure (through a lower thermic effect of food) with the consumption of high-sugar rather than mixed-nutrient beverages.[26]

In a randomized, crossover study in adults, a sugar-only beverage resulted in higher subsequent energy retention in the body, higher reported hunger, and lower satiety than a mixed-nutrient beverage with a matching carbohydrate source.[26] Nevertheless, it is too early to rule out the possibility that milk intake and the intake of high-sugar beverages exert their effects via separate mechanisms and that there may be energy-independent effects in children. In adults, the effect of dairy appears to be energy-dependent despite a potentially biological basis for dairy calcium and other dairy components in the modulation of adiposity (as described below), suggesting that regardless of dairy intake, increased overall energy intake would mask the potentially biological effects of dairy and lead to increased obesity[27-29]; however, this is unclear in children.[30,31] Dairy intake may be associated with other healthy lifestyles that promote weight control and metabolic health, while soda intake may be associated with poor eating habits that promote ill health. More research on eating patterns is needed before the correlational and causal associations among dairy intake, intakes of soda and other high-sugar beverages, total energy intake, and risk of obesity can be determined.

Potential Biological Basis for the Effects of Calcium and Other Dairy Components

As described in detail by Zemel and Miller[32] in a review that appeared recently in this journal, dietary calcium appears to play a critical role in the regulation of energy metabolism, such that increased dietary calcium reduces 1,25-dihydroxyvitamin D activity and intracellular calcium influx, resulting in a decrease in fatty acid synthase transcription in adipocytes and a decrease in insulin secretion by the pancreas.[33] Consequently, lipogenesis and insulin secretion are both reduced and lipolysis is enhanced, resulting in a net fat loss.[33]

In addition to the role of dietary calcium, additional dairy-derived bioactive compounds may help to explain the augmented effect of whole dairy food intake versus calcium supplementation alone, as seen in a few recent studies.[32] It is suggested that the whey fraction of milk—a rich source of bioactive compounds—may act independently or synergistically with calcium to attenuate lipogenesis, accelerate lipolysis, and/or influence nutrient partitioning between adipose and skeletal tissues.[34] Whey proteins were recently shown to exhibit strong angiotensin-converting enzyme inhibitory activity.[35,36] Angiotensin-converting enzyme is necessary for the cleavage of angiotensin I to form angiotensin II, the active agent in the renin-angiotensin system that is known to cause arteriole constriction. However, adipocyte lipogenesis has been shown to be regulated also in part by angiotensin II,[37] suggesting that whey protein has the ability to inhibit fat deposition in addition to its potentially anti-hypertensive effect. Furthermore, the amino acid leucine, a component of whey protein, may contribute independently to the beneficial effect of dairy on the partitioning of dietary energy.[38]

In brief, while there appears to be some biological justification for the potentially anti-obesity effect of dietary calcium and a possibly augmented effect of whole dairy foods, evidence to date is still limited, and it is not clear how these potential biological modulations differ in different segments of the population or how much variance they explain in obesity or metabolic functioning relative to other eating pattern variables. No studies have specifically examined these mechanisms in children and adolescents. The dynamic metabolic changes during growth and puberty may complicate these issues in these groups.

Association of Dairy and Calcium Intake with Obesity

Several recent studies have shown an inverse relationship between dairy intake and obesity. However, results have been inconsistent among studies, with most showing no effect of dairy on weight or body fat change. In addition, compared with adults, very little research has been done in children and adolescents. Of the studies available in children and adolescents, we describe those showing significant compared with no effects of dairy below (see Table 1 for a summary).

Studies Showing Significant Effects of Dairy

All of the studies showing a beneficial role of dairy in children are observational in nature. One of these studies was conducted among children followed from 2 to 8 years of age in Tennessee, where higher mean longitudinal calcium intakes and daily servings of dairy products were associated with lower body fat, independent of total energy intake.[31,39] A 300-mg increment of calcium intake in these children was associated with approximately 1 kg less body fat.[40] In addition, in the same cohort of children, when prediction models for percent body fat were examined according to dietary variables, parental obesity, and sedentary activity, low calcium intake (but not total energy intake) was consistently retained as a significant predictor, explaining 2% to 9% of the variance in percent body fat.[31] Body fat in these children was measured by dual-energy x-ray absorptiometry. However, for reasons that are unclear, BMI was adjusted as a covariate when body fat was the outcome. Nevertheless, the direction and magnitude of the effect of calcium intake in the above study was surprisingly similar to those found in a separate cross-sectional study among 9- to 14-year-old girls living in Hawaii, also independent of energy intake and physical activity.[41] In this latter study, replacing calcium intake with dairy intake as an independent variable in multivariate regression analysis resulted in a higher R^2, suggesting that dairy intake may explain more variance in both body weight and iliac skin-fold thickness compared with calcium intake.

More recently, as part of the Framingham Children's Study, Moore et al.[42] examined children from 3 to 5 years of age through early adolescence and found that higher intakes of calcium were associated with lower gains in body fat over time, and that increasing servings of dairy intake were even more strongly correlated, corroborating findings from Novotny et al.[41] and other findings in adults that whole dairy foods may provide added protection compared with dietary calcium. Average gains over 8 years in the sum of 4 skin-folds (triceps, subscapular, suprailiac, and abdominal) were 8.6, 4.6, and 4.7 mm/year from the lowest to the highest tertiles of daily dairy intake.[42] These researchers also found that the effect of dairy was independent of total energy intake and physical activity, though they note that the difficulty in assessing energy intake accurately may interfere with the ability to truly examine total energy intake as a confounder (Moore LL, personal communication, July 22, 2004).

Daily frequency of dairy intake has also been found to be inversely associated with obesity in low-income Puerto Rican children living in Hartford, CT, where dairy intake of at least once a day was associated with a 59% lower risk of having a BMI ≥ 85th percentile.[43] Television viewing was co-varied as a proxy of physical inactivity. However, total energy intake was not examined as a covariate in multivariate analyses, and frequency of dairy intake provides no information on the quantity of dairy intake necessary for a protective effect.

Studies Showing No Effects of Dairy

Contrary to the above observational studies, in which a protective effect of dairy was reported, two other observational studies and all of the intervention studies to date have not shown any effect of dairy.

Observational Studies. Longitudinal data from the MIT Growth and Development Study found no relationship between dairy food or calcium consumption and body fat in adolescent girls.[44] Normal-weight girls 8 to 12 years were followed until 4 years post menarche. Outcomes included BMI Z-scores and percent body fat as measured by bioelectrical impedance analysis. In separate mixed models, these researchers examined daily servings of dairy, percent daily calories from dairy foods (low-fat foods separated out or not), and dairy calcium based on repeated measures over several years. While percent daily calories of caloric beverages, snacks, ma-

Table 1. Studies Showing an Effect Versus No Effect of Dairy and/or Calcium on Weight and Body Composition

First Author	Subjects	Design	Precisely-Measured Adiposity Outcomes Reported	Results
Studies Showing Significant Effects of Dairy				
Skinner[31] Carruth[39]	53 US white children initially 2 y old	Longitudinal study; followed until 8 y old	Yes	Calcium intake explained 2% to 9% of the variance in body fat independent of total energy intake and sedentary activity
Novotny[41]	323 girls in Hawaii 9–14 y old	Cross-sectional study	No	Dairy intake, age, and physical activity together explained 17.2% of the variance in iliac skinfold thickness. Replacing dairy intake with calcium intake reduced the R^2 to 15.3%.
Moore[42]	95 US children initially 3–5 y old	Longitudinal study; followed for 8 y	No	Gains in the sum of triceps, subscapular, suprailiac, and abdominal skinfold thicknesses were 8.6, 4.6, 4.7 mm/y from the lowest to the highest tertiles of dairy intake/day, independent of total energy intake and physical activity
Studies Showing No Effects of Dairy				
Phillips[44]	196 US girls initially 8–12 y old	Longitudinal study; followed for 10 y	No	No effect of daily servings of dairy, percent calories from dairy/day, or dairy calcium on anthropometry
Lin[45]	1651 school-age children representative of US population	Cross-sectional study	No	No effect of dairy intake on BMI
Chan[48]	48 US girls initially 11 y old	RCT of dairy product supplementation (to total 1200 mg Ca/d) for 1 y	Yes	No significant difference in gain of weight, height, body fat, or lean tissue
Cadogan[47]	82 UK girls initially 12 y old	RCT of 568 mL/d extra milk for 18 mo	Yes	No significant difference in gain of weight, height, body fat, or lean tissue
Merrilees[46]	91 New Zealand girls, initially 15–16 y old	RCT of dairy foods (1000 mg Ca/d) for 2 y	Yes	No significant difference in gain of weight, height, body fat, or lean tissue
Dibba[55]	160 Gambian children initially 8–12 y old	RCT of 1000 mg (5 d/wk) $CaCO_3$ for 1 y	No	No significant difference in gains of weight, height, skinfolds, or mid-upper arm circumference
Johnson[54]	45 pairs of US identical twins initially 6–14 y old	RCT of 1000 mg/d calcium citrate malate for 3 y	No	No significant difference in weight or height gain
Lee[53]	84 Hong Kong children initially 7 y old	RCT of 800 mg/d $CaCO_3$ for 18 mo	No	No significant difference in weight or height gain
Lee[52]	162 Chinese children initially 7 y old	RCT of 500 mg/d calcium citrate malate for 18 mo	No	No significant difference in weight or height gain
Lloyd[51]	94 US girls initially 12 y old	RCT of 500 mg/d calcium citrate malate for 18 mo	Yes	No significant difference in gain of weight, height, or % body fat
Bonjour[50]	149 Swiss girls initially 8 y old	RCT of food products with calcium (850 mg/d) from milk extract for 1 y	No	No significant difference in weight or height gain
Nowson[49]	42 pairs of Australian female twins initially 10–17 y old	RCT of 1000 mg/d $CaCO_3$/Ca lactate for 18 mo	No	No significant difference in weight or height gain

RCT = randomized controlled trial.

cronutrients, and physical activity were considered as covariates, this study did not help answer the question of whether the effect of dairy is dependent or independent of total energy intake. The lack of precise measures of body composition was also a limitation.

In addition, among school-age children from CSFII 1994-1996 and 1998, Lin et al.[45] did not find any relationship between dairy intake and BMI independent of gender, ethnicity, television viewing, and socioeconomic status. The strength of this study was in the use of a nationally representative sample of children and the inclusion of several other eating pattern variables as covariates. However, dairy intake, based on the proxy of low-fat milk consumption, was based on a single-item survey and not a dietary recall, food frequency questionnaire, or other more precise technique of measuring dietary intake. Total energy intake was also not examined as a potential confounder in this study.

Intervention Studies. In a review of randomized controlled trials by Barr,[29] which included three dairy product supplementation trials[46-48] and seven calcium supplementation trials in children and adolescents,[49-55] no significant differences in body weight or body composition change were detected in any of those studies. Of the three dairy food supplementation trials in children, 11- to 16-year-old girls in the United States,[48] the United Kingdom,[47] and New Zealand[46] were studied from 1 to 2 years. Milk[47] or multiple dairy food supplementation[46,48] amounting to approximately 700 to 1200 mg of calcium per day was compared with the usual diet. Outcomes included changes in weight, height, and fat and lean tissue mass as measured by dual-energy x-ray absorptiometry.

Calcium supplementation trials were conducted in boys and girls in the Gambia[55] and Hong Kong,[52,53] in identical twins in the United States[54] and Australia (girls only),[49] and in girls in the United States[51] and Switzerland.[50] With the exception of the Australian twins,[49] who were in their adolescence, all other studies included primary school-age children. Studies compared 300 to 1000 mg of calcium supplementation with placebo and ranged from 1 to 3 years in duration. Outcome measures included weight, height, skin-folds, mid-upper arm circumference, and dual-energy x-ray absorptiometry-measured fat and lean tissue mass.

Overall, compared with those studies (observational) showing a protective effect of dairy or calcium intake, the randomized trials were better controlled and the dairy food supplementation trials all included precise measures of body composition outcomes. However, these trials have not offered much insight into the potential effect of dairy or calcium intake on dynamic changes of body composition during growth and puberty due to their limited duration, age selection, and limited longitudinal analyses. In addition, the potentially confounding effect of puberty may be problematic in trials of children with mixed age groups. The difficulty in precisely measuring energy intake in free-living subjects makes findings between treatment and control groups difficult to interpret. The lack of monitoring of dietary compliance may also be problematic in assessing the true dietary consumption among participants of different intervention groups. Similar to studies showing a beneficial effect of dairy, physical activity, when considered, was usually not directly measured.

Association of Dairy Intake with the Metabolic Syndrome

Beyond obesity outcomes, a few studies, mostly in adults, have examined metabolic indices in relation to dairy intake, and some have suggested that increased dairy and/or calcium may decrease the risk for various diseases such as hypertension,[56-58] coagulopathy,[59] coronary artery disease,[60,61] and stroke,[62,63] all of which are related to obesity and the metabolic syndrome. Pereira et al.[64] recently found that among young, overweight adults in the CARDIA study, dairy consumption (100% dairy foods plus foods with dairy as the main ingredient) was inversely associated with the incidence of all components of the metabolic syndrome over 10 years, independent of ethnicity, gender, other lifestyle factors, and macronutrient and micronutrient intakes. Each daily occurrence of dairy consumption was associated with a 21% lower chance of having at least two components of the metabolic syndrome. Because caloric contents of different food groups were covaried statistically, total energy intake was not examined as a potential confounder. In addition, similar to the study in Puerto Rican children,[43] the use of frequency as a measure of dairy intake is not ideal and makes the finding difficult to interpret.

To our knowledge, only one study has investigated the relationship between dairy intake and components of the metabolic syndrome in children.[65] In a cross-section of African-American and white children (mean age, 9 years), total cholesterol, triacylglycerol, insulin sensitivity, and acute insulin response were regressed on daily servings of dairy, fruit, grains, meat, and vegetables, daily intakes of added sugar, and discretionary fat, body fat, socioeconomic status, and ethnicity. Results showed that dairy intake was not significantly related to total cholesterol, triacylglycerol, insulin sensitivity, or acute insulin response. This study, however, relied on a small group of pre- and early-pubertal children only. In addition, because the effect of dairy intake was not a primary question, no additional analyses were done to examine different cutoffs and definitions of dairy intake. Finally, no data were available on the effects of dairy intake on longitudinal changes in metabolic profiles during growth and puberty. One other study in urban minority adolescents at risk for hypertension showed that diets rich in minerals and vitamins, including calcium, were associated with lower blood pressure, suggesting the possibility that diets that include dairy products may be worthy of investigation as a way to prevent hypertension at a young age.[66]

Summary of Dairy Associations with Obesity and the Metabolic Syndrome

Collectively, findings across studies to date fail to demonstrate compellingly a beneficial effect of dairy intake in children and adolescents. There are very few longitudinal data on dairy in relation to precisely measured changes of body composition or metabolic functioning during growth. Methodological issues such as inconsistent definitions of exposure and outcome variables, as well as the lack of control for other dietary variables that may be potentially confounding, might have led to discrepant findings and make studies difficult to compare and interpret. Dietary reports that are implausible or unrepresentative of usual intake and the lack of dietary compliance monitoring during intervention trials are also significant problems. These issues are further discussed below.

Qualification and Quantification of Dairy Intake

A major barrier to the interpretation of findings across studies on dairy intake is the lack of consistent and thorough examination and/or reporting of the different definitions of dairy intake across studies. Defining dairy intake involves the careful consideration of what constitutes a dairy food. For example, should dairy-based desserts such as flavored milks, flavored yogurts, ice creams, puddings, lattés, etc., be counted? If so, does the benefit of dairy outweigh the potentially adverse effects from the excess calories of added sugar in these food items? In part, this relates to whether the effect of dairy is independent of total energy intake in children and adolescents during growth. If the effect of dairy is unique, then sweetened or flavored dairy products may be an alternative and more appealing way to increase dairy consumption in children and adolescents. Recent surveys show that children and adolescents are more likely to meet recommended calcium intakes and have a greater overall number of dairy servings a day if they consume sweetened dairy products.[4]

Apart from deciding what qualifies as dairy, studies to date have been inconsistent in the examination of amount versus frequency of dairy intake in relation to health outcomes. As mentioned previously, frequency does not imply any quantity, thus making the interpretation of findings very difficult. In addition, there is little research on determining a cutoff level for these different units at which a protective or adverse effect of dairy can be observed.

Fat Content of Dairy and Milk

Whole and 2% milk are a major source of unsaturated fatty acids among US children and adolescents.[67] The fact that dairy is often associated with a high fat content may have contributed to the decrease in dairy, especially milk, intake. However, dairy intake does not seem to increase the overall consumption of dietary fats.[68] Nevertheless, in adults, most studies showing a benefit of dairy intake have included non- and low-fat milk intake because the effect of dairy in adults appears to be energy dependent. Compared with whole milk, non-fat milk contains just half the calories and the same bioactive nutrients. In children and adolescents, no studies have examined whether different associations between dairy intake and health outcomes might exist based on the consideration of dairy and milk of differing fat content. More studies are needed to examine whether high-fat dairy and low-fat dairy have different effects on changes in body composition and metabolic profiles during growth.

Potentially Spurious Findings Due to Implausible Dietary Reports

The widespread problem of physiologically implausible dietary reports may have in part contributed to the inconsistent relationships between dairy and health.[22,69-71] In previous research, including our own,[22,69,71] an implausible dietary energy report has been defined as one that is inconsistent with energy requirements. An implausible dietary report may be due to recall bias or unusual intakes (e.g., due to sickness or a celebration event) on the day(s) of dietary assessment. Underreporting has been shown to result in a 10% to 50% underestimation of actual energy intake.[72,73] In some studies, the proportion of nutrients was also thought to be affected.[74-76] The fact that implausible reporting can be both variable and substantial makes it difficult to detect and interpret relationships between diet and health.

In children, the extent of reporting bias may increase with age[70] and be larger in obese relative to lean children.[77] Recently, we found that overreporting and/or overeating is a significant problem in children under 12 years of age, a time when parents or caretakers assist in dietary recalls, whereas underreporting and/or undereating is a major problem in adolescents.[22]

Using a method we developed to identify implausible dietary reports, in which we statistically and biologically compared reported energy intake with predicted energy requirements,[69] we showed that the careful exclusion of implausible dietary reports had a significant impact on observed diet-obesity relationships.[22] For instance, in a US national sample of children and adolescents, energy intake was not related to BMI percentile before the exclusion of implausible dietary reports; however, it became strongly and positively related to BMI percentile after the exclusion of implausible reports.[22] This latter finding is more consistent with recent literature on the role of energy regulation in weight maintenance,[78] and suggests that the failure to consider the plausibility of dietary reports could lead to spurious findings.

Future research needs to address this problem so that dairy-health associations may be better interpreted and compared across studies, and total energy intake and other potentially confounding dietary variables may be adjusted for appropriately during analysis. Also, it is not clear to what extent dairy may be, if at all, under- or overreported among children and adolescents. Future studies aimed at developing valid and reliable biological markers of dairy intake as a way to better assess dairy intake may also be useful, particularly for compliance monitoring during dairy intervention trials. The lack of adequate compliance monitoring may distort the effect of dairy intake in free-living conditions and may also make it difficult to study other confounding dietary effects.

Conclusions

The majority of studies, including all existing clinical trials, do not yet support a protective role of dairy intake against obesity or the metabolic syndrome in children and adolescents. If there are effects of dairy, however, it is not clear whether they are independent of other eating patterns such as intake of sweetened beverages or overall energy intake. These potentially confounding variables are often not controlled for in analyses using observational data or checked for using rigorous compliance monitoring techniques in intervention trials. In addition, even when these potentially confounding dietary variables are adjusted for during analysis, the difficulty in measuring diet accurately poses difficulty in the interpretation of these effects (or the lack thereof).

Furthermore, while there is some biological evidence for a beneficial role of dairy, these physiological pathways have not been examined in children and adolescents. Associations between dairy intake and growth-related changes in body composition (with precise measures) and metabolism are very much understudied. More long-term studies are warranted. Data in minority children and adolescents at high risk for obesity and metabolic dysfunctions are also critically lacking. Future research can be enhanced by an added emphasis on carefully defining dairy consumption and improving the quality of dairy intake data. More studies in children and adolescents are urgently needed before important dietary recommendations can be made and prevention interventions designed.

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