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Review Article

The association of flavored milk consumption with milk and energy intake, and obesity: A systematic review

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ABSTRACT

Taxes on sugary drinks are being implemented to prevent chronic diseases. Sugar-sweetened milk has been exempt from such policies because of its nutritional value. This systematic review sought to examine whether flavored milk consumption was associated with milk and energy intake, and obesity among children.

A search of PubMed, EMBASE, Cochrane, CINAHL, Web of Science, Cochrane Central Register of Controlled Trials and the grey literature was conducted for peer-reviewed publications published before June 6, 2016 that met the following criteria: 1) English-language publications 2) studies of children ages 1 to 18 years, 3) controlled experimental, cohort, case-control, systematic reviews, or meta-analysis studies 4) dependent variable: flavored milk consumption 5) independent variable: weight, weight gain, weight change, body mass index, metabolic syndrome, waist circumference, cholesterol, triglycerides, blood pressure, serum glucose, calories, sugar, or milk consumed.

Of 3978 studies identified, 13 met inclusion criteria. Ten studies were experimental and three were longitudinal cohort studies. Eleven studies found that flavored milk increased overall milk intake, five of seven studies that examined energy intake showed that flavored milk increased energy intake, and one of three studies that assessed obesity outcomes demonstrated an increase in weight gain with flavored milk consumption. Only one study was a randomized controlled trial, most studies had high bias, and over half were industry-funded or did not disclose funding.

Although flavoring milk may increase milk intake, added sugars may promote increased energy intake. More data regarding flavored milk's impact on health is needed to inform its role in sugary drink policies.

1. Introduction

Sugar sweetened beverages (SSBs) are the largest single dietary source of added sugars (Reedy and Krebs-Smith, 2010), and their intake is associated with obesity (Te Morenga et al., 2012) and type 2 diabetes (Malik et al., 2010a; Hu and Malik, 2010; Malik et al., 2010b). Due to concerns about the health consequences of SSB intake, scientific authorities recommend limiting consumption of these beverages (Johnson et al., 2009).

As SSB intake has risen, consumption of vitamin D-, calcium-, and protein-rich milk, has declined (Dror and Allen, 2014). Growing youth are particularly vulnerable to decreases in milk intake; while they consume sufficient protein, they do not meet recommended dietary allowances (RDA) for vitamin D and calcium which promote bone health (Anon, n.d.; United States Department of Agriculture, n.d.-a; United States Department of Agriculture, n.d.-b).

Abbreviations: SSB, Sugar-sweetened beverages; BMI, Body mass index; RDA, Recommended daily allowance; ML, Medical librarian; CINAHL, Cumulative index to nursing and allied health literature; CENTRAL, Cochrane Central register of controlled trials; RCT, Randomized controlled trials; PRISMA, Preferred reporting items for systematic reviews and meta-analyses guidelines; AMSTAR, Assessing the methodological quality of systematic reviews; CI, Confidence interval

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Adding sugar to milk has emerged as a way to promote its intake. Endorsed by the American Academy of Pediatrics and other organizations (Johnson et al., 2009; Anon, 2015; Position of the American Dietetic Association, 2004), flavored milk is provided in over 50% of U.S. schools (O'Toole et al., 2007) and a quarter of preschoolers consume it daily (Fulgoni and Quann, 2012). Although nutrient-rich (Fayet-Moore, 2016), eight ounces of flavored milk contains half of a child's daily allotment of added sugar (Johnson et al., 2009), and is a top contributor of sugar and fat intake in schools (Poti et al., 2014).

Given the ubiquity of flavored milk and the controversy surrounding its consumption, it is important to provide sound evidence on the health impacts of drinking flavored milk. Although an earlier review examined flavored milk consumption's association with milk intake and nutrient provision in children (Fayet-Moore, 2016), in our examination the review only met one of 11 Assessing the Methodological Quality of Systematic Reviews (AMSTAR) criteria and was funded by Nestle Australia Ltd., a leading flavored milk manufacturer.

The objective of this study was to conduct a systematic review to examine if flavored milk consumption was associated with intake of milk and energy, and obesity among children and adolescents. Study findings could have important implications regarding whether flavored milk should be offered through school and child care meal programs (7 CFR 210.11a, n.d.) and if the beverage should be treated like other SSBs in increasingly popular "soda" taxation policies (Falbe et al., 2015; Colchero et al., 2015).

2. Methods

2.1. Data sources

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement to guide this review (Fig. 1) (PRISMA, n.d.). The first author (AP) and a medical librarian (ML) searched six databases: PubMed, Embase, Cochrane Database of Systematic Reviews, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL) up to June 06, 2016. Search strategies were developed to identify studies that examined the association of flavored milk consumption with our primary outcomes, obesity and metabolic syndrome, and our secondary outcomes of overall intake of milk, added sugar, and calories.

Search terms were as follows: (((milk [mh:noexp] OR milk)) AND (((((flavored OR flavored OR flavoring OR flavor OR sweetened OR sweetening OR sweetener OR sweeteners OR chocolate OR sugar OR sugars OR syrup OR sucrose OR fructose OR cocoa OR cacao)) OR (sweetening agents [mh] OR non-nutritive sweeteners [mh] OR nutritive sweeteners [mh] OR dietary sucrose [mh] OR high fructose corn syrup [mh] OR sucrose [mh] OR cacao [mh]))) OR (((("flavored milk" [tiab]) OR "flavored milk" [tiab]) OR "sweetened milk" [tiab]) OR "chocolate milk" [tiab]))) AND (child [mh] OR child, preschool [mh] OR preschooler OR preschoolers OR child OR children OR childhood OR adolescent [mh] OR adolescents OR adolescence OR teen OR teens OR teenager OR teenagers OR youth OR youths). Additional studies were identified through searching the key grey literature and reference lists of papers included in the final analysis.

2.2. Study selection

The references were imported into Covidence, an electronic platform for systematic reviews and meta-analysis, which has been selected by Cochrane to be the standard platform for Cochrane reviews (Covidence, n.d.). Duplicates were removed and two study authors independently reviewed titles and abstracts to include or exclude studies in the Covidence platform. Any disagreements between the two reviewers were resolved by the first author (AP).

Inclusion criteria for studies were determined in advance and included the following: (1) peer-reviewed; (2) published in English; (3) available in full text; (4) focus on children and adolescents ages 1 to 18 years old; (5) study designs that included randomized controlled trials, other controlled experimental studies, cohort studies, case-control studies, systematic reviews, or meta-analyses; (6) exposure variable included flavored milks with added sugar measured as either an any or none indicator, as frequency of consumption, or in total fluid oz.; and (7) outcome variable that included one of the following: weight, weight gain, weight change, body mass index (BMI), metabolic syndrome, waist circumference, cholesterol, triglycerides, blood pressure, serum glucose, calories, sugar, or overall milk consumed. Cross-sectional studies, case-studies, and correlational studies, were excluded because while these descriptive studies examine relationships between flavored milk consumption and outcomes at a single point in time, they do not explore causal relationships, such as whether a change in flavored milk consumption leads to a change in outcomes. If more than one article was published from the same cohort, only the study with the largest sample size was included, unless a different outcome variable was used.

2.3. Data extraction

Two reviewers independently extracted data from studies, including information about the study identification, methods, population, interventions, and outcomes into the Covidence platform. Risk of bias was assessed using the Cochrane risk of bias tool. Discrepancies were resolved by the first author (AP).

A descriptive characterization of studies including information about study identification (country, year of publication, sponsorship), methods (study design), population (inclusion and exclusion criteria and group differences), interventions, and outcomes were summarized. A meta-analysis of the three studies examining mean differences for change in body weight and BMI were conducted using a random effects model to generate summary differences and 95% confidence intervals (CIs). Study outcomes were adjusted to have consistent follow-up time periods. Statistical heterogeneity was assessed by using the I^2 and Cochran's Q statistics. All analyses were conducted using Stata v.14.2, College Station, TX.

3. Results

The searches identified 5762 abstracts with 3978 remaining after duplicates were removed. Of the 209 studies that met the initial criteria for full text review, 13 met inclusion criteria and were qualitatively summarized (Albala et al., 2008; Garey et al., 1990; Gopinath et al., 2014; Guthrie, 1977; Hanks et al., 2012; Henry et al., 2015; Henry et al., 2016; Noel et al., 2013; Quann, 2013; Vanselow et al., 2009; Wilson, 1991; Wilson, 1994; Wilson, 2000). Of the 13 studies included in this review, three met inclusion criteria for the meta-analysis (e.g., examined a difference in weight or BMI over time between children drinking flavored milk versus children drinking no or lower amounts of flavored milk) (Albala et al., 2008; Noel et al., 2013; Vanselow et al., 2009). Two studies examined a mean difference in weight (Albala et al., 2008; Noel et al., 2013) and two a mean difference in BMI (Albala et al., 2008; Vanselow et al., 2009). Due to the small number and high heterogeneity (I^2 of 95.2 to 98.5%) of studies, meta-analysis results are not reported. A summary of the flow of studies through the systematic review and meta-analysis process, including reasons why studies were excluded is shown in Fig. 1.

3.1. Characteristics of included studies

Studies included in qualitative analysis are summarized in Tables 1 and 2. Seven studies were conducted in the United States (Garey et al., 1990; Guthrie, 1977; Hanks et al., 2012; Quann, 2013; Vanselow et al., 2009; Wilson, 1991; Wilson, 2000), two in Canada (Henry et al., 2015; Henry et al., 2016), one in Australia (Gopinath et al., 2014), one in

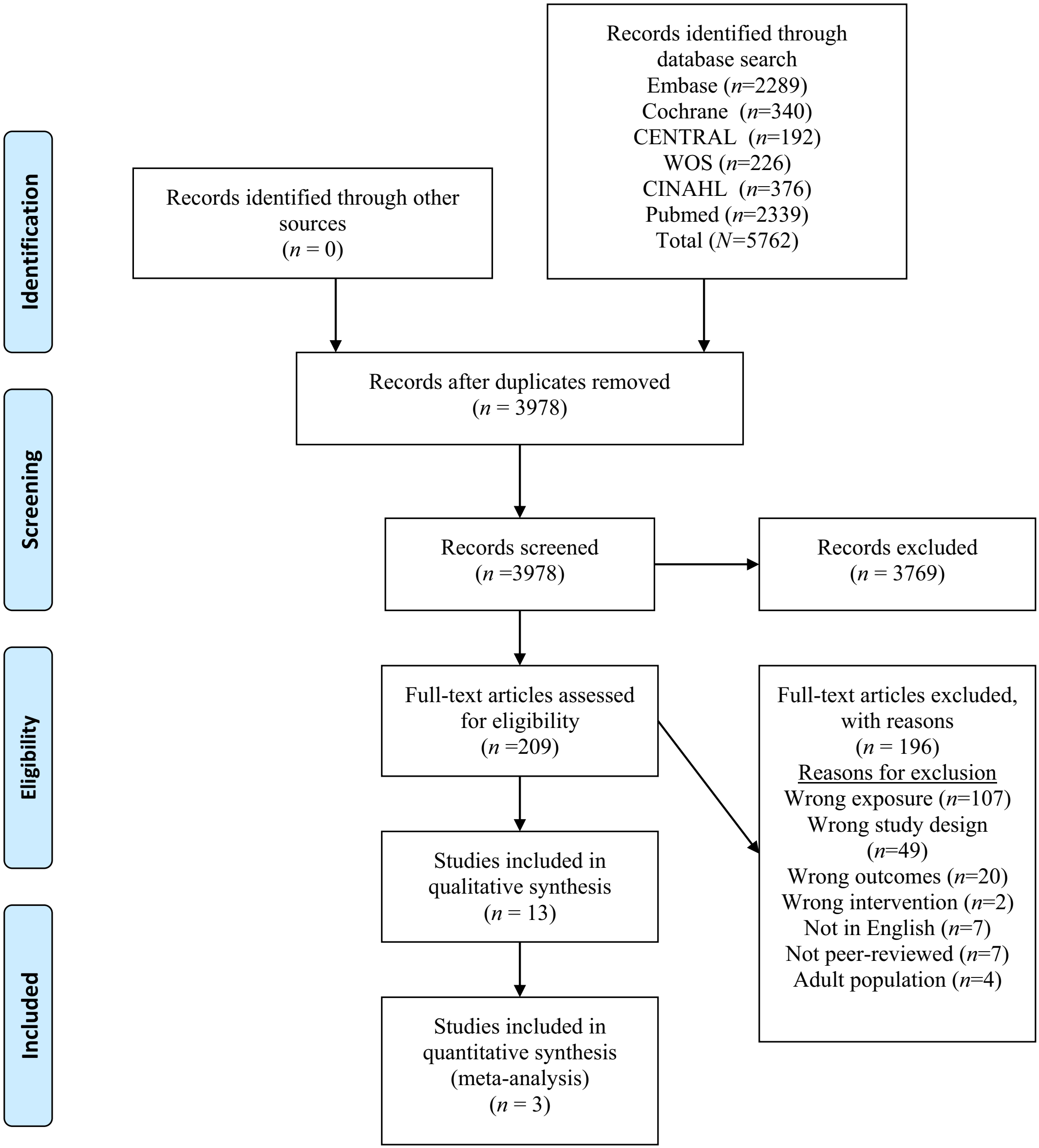
Identification
Screening
Eligibility
Included
Records identified through database search
Embase (n=2289)
Cochrane (n=340)
CENTRAL (n=192)
WOS (n=226)
CINAHL (n=376)
Pubmed (n=2339)
Total (N=5762)
Records identified through other sources
(n = 0)
Records after duplicates removed
(n = 3978)
Records screened
(n =3978)
Records excluded
(n = 3769)
Full-text articles assessed for eligibility
(n =209)
Full-text articles excluded, with reasons
(n = 196)
Reasons for exclusion
Wrong exposure (n=107)
Wrong study design (n=49)
Wrong outcomes (n=20)
Wrong intervention (n=2)
Not in English (n=7)
Not peer-reviewed (n=7)
Adult population (n=4)
Studies included in qualitative synthesis
(n = 13)
Studies included in quantitative synthesis (meta-analysis)
(n = 3)

Table 1
Characteristics of reviewed studies.

Study: first author, year, design, reference #	Setting: location, time period, data source, sponsorship	Subject characteristics: age, sample size, sex, racial/ethnic composition	Interventions: treatment, duration	Outcomes: obesity, weight, weight gain	Outcomes: energy intake	Outcomes: total milk intake
Albala et al., 2008, randomized controlled trial	Chile, 16 weeks, food frequency questionnaires, wt/ht. measurements, Fogarty International Center, National Institutes of Health	8–10 years, $N = 98$, 47% female	Home chocolate milk deliveries for subject and/or any siblings Nutritionist provided instructions to consume 3 servings of milk per day and to not drink other sugar-sweetened beverages Nutritional content of 200 ml serving of chocolate milk: 80 kcal, 8 g protein, 3 g fat, 11 g carbohydrate	Mean Δ in wt, kg ± SE Intervention 1.57 ± 0.24; Control 1.13 ± 0.24 ($p = 0.20$) Mean Δ in BMI, kg/m^2 ± SE Intervention 0.08 ± 0.12; Control −0.09 ± 0.12 ($p = 0.33$) Mean Δ in BMI z score ± SE Intervention 0.01 ± 0.02; Control −0.01 ± 0.02 ($p = 0.58$) Mean Δ in lean mass, kg ± SE Intervention 0.92 ± 0.10; Control 0.62 ± 0.11 ($p = 0.04$)	Mean Δ in energy intake, kcal/d ± SE Intervention −91.0 ± 33.0; Control 9.7 ± 29.8 ($p = 0.03$)	Mean Δ in milk intake, g/d ± SE intervention 452.5 ± 37.7; control 11.3 ± 11.3 ($p < 0.0001$)
Garey et al., 1990, experimental crossover	New York City, New York, USA, 3-weeks, wt of foods and beverages consumed, sponsorship not specified	11–14 years, $N = 32$–64, 60% female	Fixed experimental meals offered 9 times over a 3-week period with a random pairing of 1%-fat chocolate milk, 1%-fat plain milk, or 3.5%-fat plain milk with the meal Nutritional content of milk not reported		Mean energy intake of meals served with a given beverage, kcal 1%-fat chocolate milk: 551, 1%-fat plain milk: 450, 3.5%-fat plain milk: 553 (no p-value noted)	Milk consumption with test meal with a given beverage (% consumed) Meal 1: Chocolate 90.5, 1%-fat plain 41.6, 3.5%-fat plain 74.4 ($p < 0.01$) Meal 2: Chocolate 91.4, 1%-fat plain 50.1, 3.5%-fat plain 72.5 ($p < 0.01$) Meal 3: Chocolate 93.6, 1%-fat plain 40.8, 3.5%-fat plain 45 ($p < 0.01$)
Gopinath et al., 2014, longitudinal cohort	Sydney, Australia, 2004–2011, surveys, Australian National Health & Medical Research Council, Westmead Millennium Institute, University of Sydney, Vision Co-operative Research Centre, University of New South Wales, National Heart Foundation of Australia, Dairy Australia	12–17 years, $N = 634$, 55% female	Frequency of flavored milk consumption per week: Frequent (≥2250 ml servings/wk), infrequent (< 2250 ml servings/wk) Nutritional content of milk not reported			Odds of > median milk consumption among frequent flavored milk consumers as compared to infrequent flavored milk consumers [OR (CI): 4.74 (2.66–8.44)]

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Table 1 (*continued*)

Study: first author, year, design, reference #	Setting: location, time period, data source, sponsorship	Subject characteristics: age, sample size, sex, racial/ethnic composition	Interventions: treatment, duration	Outcomes: obesity, weight, weight gain	Outcomes: energy intake	Outcomes: total milk intake
Guthrie, 1977, experimental crossover	Pennsylvania, USA, November to February, wt of foods and beverages consumed, Chocolate Manufacturer's Association	Grades 1–6, $N = \sim400$	Six test meals offered in schools with the option of chocolate milk or plain milk or plain milk only Nutritional content of chocolate milk: 213 kcal, protein 8.5 g, calcium 278 mg, iron 0.5 mg, vitamin A 325 iu, thiamin 0.08 mg, riboflavin 0.40 mg, ascorbic acid 5 mg Nutritional content of plain milk: 160 kcal, protein 9 g, calcium 288 mg, iron 0.1 mg, vitamin A 350 iu, thiamin 0.07 mg, riboflavin 0.40 mg, ascorbic acid 2 mg		Mean energy intake of meals served with a given beverage, kcal ± SD Grade 1–5 Plain milk only: 535 ± 94, Chocolate or plain milk: 563 ± 64 Grade 6 plain milk only: 567 ± 36, Chocolate or plain milk: 627 ± 101 Grade 1–6 plain milk only: 551 ± 113, Chocolate or plain milk: 595 ± 87 (no *p*-values noted as significant)	Milk wasted, oz./child ± SD Grade 1–5 plain milk only: 1.36 ± 0.24, Grade 1–5 chocolate or plain milk: 0.39 ± 0.08 ($p < 0.001$) Grade 6 plain milk only: 0.94 ± 0.12, Grade 6 chocolate or plain milk: 0.44 ± 0.08 ($p < 0.01$) Grade 1–6 plain milk only: 1.15 ± 0.29, Grade 1–6 chocolate or plain milk: 0.42 ± 0.08 ($p < 0.001$)
Hanks et al., 2012, experimental crossover	Corning, NY, USA, 16 weeks, wt of milk consumed, Economic Research Service, United States Department of Agriculture	$N = 602$ observations prior to healthier line, $N = 482$ observations after healthier line	Healthier food and flavored milk (chocolate or strawberry) line in school cafeterias Nutritional content of milk not reported			Total milk consumed per student, grams ± SEM Control: 218.6 ± 5.29, Intervention: 234.6 ± 5.28; ($p = 0.04$)
Henry et al., 2015, experimental crossover	Saskatoon, Canada, 12 weeks (each phase 4 weeks), wt of foods and beverages, beverage frequency questionnaires, Dairy Farmers of Canada	Grades 1–8, $N = 1205$	Phase 1: chocolate milk and plain milk, Phase 2: plain milk, Phase 3: chocolate milk and plain milk Nutritional content of milk not reported			Mean daily milk consumed per student per day, mL ± SEM Phase 1: 225 ± 2, Phase 2: 213 ± 4, Phase 3: 227 ± 4 ($p < 0.001$) Mean total milk consumption via beverage frequency questionnaire, servings/wk. ± SEM Phase 1: 2.1 ± 0.1, Phase 2: 1.9 ± 0.1, Phase 3: 2.0 ± 0.1 ($p = 0.257$)
Henry et al., 2016, experimental crossover	Saskatoon, Canada, 6 weeks (each phase 3 weeks), wt of milk, Dairy Farmers of Canada	Grades 1–8, $N = 2124$, 49% female, mostly Caucasian	Phase 1: 1% chocolate milk and 2% plain milk, phase 2: reduced-sugar 1% chocolate milk and 2% plain milk Nutritional content: 1% chocolate milk: 250 ml serving; 160 kcal; 25 g sugar			Median total milk consumed per student per day, mL (IQR) phase 1: 220 (230–246), phase 2: 203 (214–240) ($p < 0.05$) Mean total milk consumed per student per day, mL ± SD

(*continued on next page*)

Table 1 (*continued*)

Study: first author, year, design, reference #	Setting: location, time period, data source, sponsorship	Subject characteristics: age, sample size, sex, racial/ethnic composition	Interventions: treatment, duration	Outcomes: obesity, weight, weight gain	Outcomes: energy intake	Outcomes: total milk intake
			Nutritional content of 1% reduced-sugar chocolate milk: 250 ml serving; 140 kcal; 19 g sugar Nutritional content of 2% plain white milk: 250 ml serving; 130 kcal; 12 g sugar			Phase 1: 237 ± 2, Phase 2: 225 ± 2 (significance not noted)
Noel et al., 2013, longitudinal cohort	Avon County, England, 3 years, dietary records, wt measurements, American Diabetes Association, UK Medical Research Council, Welcome Trust, University of Bristol, and National Heart, Lung and Blood Institute	10–13 years, $N = 2270$, 55% female	Flavored milk consumers and non-consumers Nutritional content of milk not reported	Δ in wt for consumers and non-consumers of flavored milk, stratified by baseline wt status, kg (CI) Normal weight Consumers: 11.1 (10.0–12.1), non-consumers: 11.1 (10.3–12.0) ($p = 0.83$) Overweight/obese consumers: 14.5 (11.1–18.0), non-consumers: 11.6 (8.8–14.4) ($p = 0.02$) Models include only plausible reporters and adjust for age, sex, height, height squared, baseline BMI, physical activity, pubertal status, maternal BMI, maternal education, and intakes of total fat, ready-to-eat cereal, fruit, vegetables, 100% fruit juice, sugar-sweetened beverages and plain milk	Energy intake for consumers and non-consumers of flavored milk at baseline adjusted for sex, mean kcals ± SE, Consumers: 2064 ± 24, Non-consumers: 1917 ± 11, ($p < 0.001$)	Consumption of flavored milk and plain milk among consumers and non-consumers of flavored milk adjusted for energy intake and sex, mean g ± SE Flavored milk consumers: 142 ± 102, Flavored milk non-consumers: 0 ($p < 0.001$) Plain milk consumers: 179 ± 153, Plain milk non-consumers: 200 ± 172 ($p = 0.02$)
Quann et al., 2013, experimental crossover	Colorado, USA, 5 months, Milk sales, measurement of milk consumption, Milk Processor Education Program, Dr. Quann is an employee of the Dairy Research Institute/ National Dairy Council	$N = 49$ elementary schools	Schools that offered plain and flavored milk were compared to schools that only offered plain milk and schools that removed flavored milk options Nutritional content of milk not reported other than the following: All districts			Mean total milk consumption on days when flavored milk is offered vs. days when it is unavailable, Oz. ± SE Flavored and plain milk: 2044 ± 61, Plain milk: 1279 ± 31

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Table 1 (*continued*)

Study: first author, year, design, reference #	Setting: location, time period, data source, sponsorship	Subject characteristics: age, sample size, sex, racial/ethnic composition	Interventions: treatment, duration	Outcomes: obesity, weight, weight gain	Outcomes: energy intake	Outcomes: total milk intake
			served low-fat and/or fat-free white milk; one district served 2% white milk; flavored milk served was low-fat and/or fat-free in all of the districts			($p < 0.001$) Mean milk consumption on days when flavored milk is offered vs. days when it is removed, Oz. ± SE Flavored and plain milk: 2044 ± 61, Plain milk 1351 ± 40 ($p < 0.001$)
Vanselow et al., 2009, longitudinal cohort	Minnesota, USA, 1998–2004, food frequency questionnaire, wt/ht. measurements, Maternal and child Health Bureau Grant	11–15 years, $N = 2294$, 55% female; 63% white, 18% Asian, 10% African American, 4% Hispanic, 3% American Indian, 3% other	Frequency of chocolate milk consumption per week: high (≥7 servings/wk), intermediate (0.5–6 servings/wk), never (0 servings/wk) Nutritional content of milk not reported	Mean Δ in BMI over 5 y, kg/m^2 ± SEM by frequency of chocolate milk intake High: 2.09 ± 0.42, intermediate: 1.77 ± 0.12, low: 1.87 ± 0.09 ($p = 0.68$) Adjusted for age, sex, race-ethnicity, socioeconomic status, baseline BMI, and baseline intake of same beverage. High: 2.43 ± 0.44, intermediate: 1.77 ± 0.12, low: 1.89 ± 0.10 ($p = 0.31$) Adjusted for all baseline beverages, baseline BMI, age, cohort, sex, race-ethnicity, socioeconomic status, baseline and time 2 strenuous physical activity, and time 2 weekday television watching and coffee and tea consumption.		
Wilson et al., 1991, experimental crossover	Springfield, Ohio, USA, 8 weeks, food and beverage measurements, Wittenberg University Faculty Research Fund Board	20–56 months, $N = 40$, 42% female	Twice a week test meals in daycare centers were served with either chocolate milk or plain milk Nutritional content of plain milk: 145 kcal/cup nutritional content of		Mean energy intake of meals served with a given beverage, kcal Meal 1: plain milk 341.6, chocolate milk 396.5 ($p < 0.02$) Meal 2: plain milk 249.7, chocolate milk 359.5 ($p < 0.01$) Meal 3: plain milk 253.4,	Mean energy intake from milk at meals served with a given beverage, g Meal 1: plain milk 138.4, chocolate milk 187.5 ($p < 0.05$) Meal 2: plain milk 101.5, chocolate milk 225 ($p < 0.01$) Meal 3: plain milk 107.6,

(*continued on next page*)

Table 1 (*continued*)

Study: first author, year, design, reference #	Setting: location, time period, data source, sponsorship	Subject characteristics: age, sample size, sex, racial/ethnic composition	Interventions: treatment, duration	Outcomes: obesity, weight, weight gain	Outcomes: energy intake	Outcomes: total milk intake
			chocolate milk: 190 kcal/cup		chocolate milk 338.1 ($p < 0.02$) Meal 4: plain milk 306.0, chocolate milk 392.8 ($p < 0.01$)	chocolate milk 215.6 ($p < 0.01$) Meal 4: plain milk 90.6, chocolate milk 218.8 ($p < 0.01$)
Wilson, 1994, experimental crossover	Date and location unspecified, 6 weeks, weight of food and beverages, sponsorship not specified	18–66 months, $N = 24$	Meals eaten at home two times/week with plain milk, sucrose-sweetened chocolate milk, or aspartame-sweetened chocolate milk Nutrition content per 8 oz. of plain milk: 145 kcal Nutrition content per 8 oz. of sucrose-sweetened chocolate milk: 235 kcal Nutrition content per 8 oz. of aspartame sweetened chocolate milk: 149 kcal		Mean energy intake of meals served with a given beverage, kcal Plain milk: 259.8 Sucrose-sweetened chocolate milk: 260.2, aspartame-sweetened chocolate milk: 267.4 (not significant but *p*-values not noted)	
Wilson, et al. 2000, experimental crossover	USA, 12 weeks, weight of food and beverages, National Institutes of Health	18–66 months, $N = 135$, 53% female	Lunch served 2 times/week with either sugar-sweetened chocolate milk vs. aspartame-sweetened chocolate milk vs. plain milk Nutrition content of plain milk: 18.1 kcal/oz. Nutrition content of sucrose-sweetened chocolate milk: 29.4 kcal/oz. Nutrition content of aspartame-sweetened chocolate milk: 18.6 kcal/oz		Mean energy intake of lunch meals served with with sugar-sweetened flavored milk vs. aspartame-sweetened chocolate milk vs. plain milk, kcal Meal 1: 388 vs. 327 vs. 315 ($p < 0.05$) Meal 2: 354 vs. 299 vs. 300 ($p < 0.05$) Meal 3: 345 vs. 294 vs. 269 ($p < 0.05$) Meal 4: 398 vs. 340 vs. 343($p < 0.05$)	Mean intake of milk at lunch meals served with sugar-sweetened chocolate milk vs. aspartame-sweetened chocolate milk vs. plain milk, oz. Meal 1: 4.6 vs. 4.5 vs. 2.8 ($p < 0.05$) Meal 2: 4.7 vs. 5.0 vs. 2.7 ($p < 0.05$) Meal 3: 4.7 vs. 4.5 vs. 2.7 ($p < 0.05$) Meal 4: 5.2 vs. 5.0 vs. 3.6 ($p < 0.05$)

Standard Error (SE), Body Mass Index (BMI), Odds Ratio (OR), Confidence Interval (CI), Standard Deviation (SD), Interquartile Range (IQR).

Table 2
Summary of changes in milk intake, energy intake, weight, BMI and BMI z-score associated with drinking flavored milk by funding source[a].

	Albala	Garey	Gopinath	Guthrie	Hanks	Henry, 2015	Henry, 2016	Noel	Quann	Vanselow	Wilson, 1991	Wilson, 1994	Wilson, 2000
Milk intake	↑	↑	↑	↑	↑	↑	↑	↑	↑		↑		↑
Energy intake	↓	↑[b]		↑[b]				↑			↑	↔[b]	↑
Weight	↔							↑[c]					
BMI	↔									↔			
BMI z-score	↔												
Funding source[d]	NI	?	I	I	NI	I	I	NI	I	NI	NI	?	NI

Body Mass Index (BMI)
[a] ↑ indicates a significant increase; ↓ indicates a significant decrease; ↔ indicates no significant change.
[b] No tests of significance or p-values reported.
[c] Significant change only noted among overweight and obese children.
[d] I indicates industry funding; NI indicates non-industry funding; ? indicates no funding disclosure.

Table 3
Risk of bias in included studies.

Study author, year, and reference #	Study design	Sequence generation	Allocation conceal-ment	Blinding of participants for outcomes	Blinding of outcome assessors for outcomes	Incomplete outcome data for all outcomes	Selective outcome reporting	Other biases
Albala et al., 2008	RCT	Low	Low	High	Low BMI; unclear calories and milk intake	Low	Low	Low
Garey et al., 1990	EC	Low	Low	High	High	Low	Low	High Small sample size, no funding source documented,aggregate data
Gopinath et al., 2014	LC	Low	Low	Low	Low	High	Low	High Funding COI
Guthrie, 1977	EC	Low	Low	High	High	Low	Low	High Funding COI, aggregate data
Hanks et al., 2012	EC	Low	Low	High	High	Low	Low	High Aggregate data
Henry et al., 2015	EC	Low	Low	High	High	Low	Low	High Funding COI, aggregate data
Henry et al., 2016	EC	Low	Low	High	High	Low	Low	High Funding COI
Noel et al., 2013	LC	Low	Low	Low	Low	Low	High	Low
Quann, 2013	EC	Low	Low	Low	Low	Low	Low	High Funding COI, aggregate data
Vanselow et al., 2009	LC	Low	Low	Low	Low	Low	Low	High Self-reported height/weight
Wilson, 1991	EC	Low	Low	High	High	High	Low	Low
Wilson, 1994	EC	Low	Low	High	High	Unclear	Low	High Funding source not provided, unclear if aggregate or individual data, no washout period, small sample size
Wilson, 2000	EC	Low	Low	High	High	High	Low	Low

Conflict of interest (COI), Experimental crossover (EC), Longitudinal cohort (LC), Randomized controlled trial (RCT).

funding of the study (Gopinath et al., 2014; Guthrie, 1977; Henry et al., 2015; Henry et al., 2016; Quann, 2013). Of thirteen studies, six were funded by foundations or governmental agencies (Albala et al., 2008; Hanks et al., 2012; Noel et al., 2013; Vanselow et al., 2009; Wilson, 1991; Wilson, 1994; Wilson, 2000), five were supported by the food or beverage industry (e.g., Dairy Council, Chocolate Manufacturers) (Gopinath et al., 2014; Guthrie, 1977; Henry et al., 2015; Henry et al., 2016; Quann, 2013), and two did not specify funding or sponsorship (Garey et al., 1990; Wilson, 1994). All industry-funded studies examined the impact of flavored milk consumption on overall milk intake; one study also examined impact of flavored milk consumption on energy intake.

3.3. Outcomes of included studies

3.3.1. The association of flavored milk intake and obesity

Three studies examined the association of flavored milk intake and obesity. In the one RCT, in which home deliveries of flavored milk were coupled with education to restrict consumption of non-milk SSBs, there were non-significant increases in the mean change in BMI and BMI z-score from pre to post intervention in the intervention group as compared to the control group that were likely due to a significant increase in lean mass (Albala et al., 2008). In a longitudinal cohort study, overweight/obese children who consumed flavored milk had a significantly greater increase in mean body weight than children who did not consume flavored milk (Noel et al., 2013). In another 5-year longitudinal cohort study, there were non-significant positive changes in BMI among children who were high frequency versus low frequency chocolate milk consumers (Vanselow et al., 2009).

3.3.2. The association of flavored milk intake and energy intake

Seven studies explored the relationship between intake of flavored milk and overall energy intake (Albala et al., 2008; Garey et al., 1990; Guthrie, 1977; Noel et al., 2013; Wilson, 1991; Wilson, 1994; Wilson, 2000). In three experimental crossover studies, in which flavored or plain milks were served with test meals in schools, a greater number of calories were consumed when flavored milk rather than plain milk was offered with the meal (Garey et al., 1990; Wilson, 1991; Wilson, 2000). When students were given the option of flavored or plain milk versus plain milk only, there were a trend toward higher mean energy intake for meals that had both milk options (Guthrie, 1977). In an experimental crossover study in the home setting, caloric intake at meals was not significantly higher when flavored milk rather than plain milk was offered with meals (Wilson, 1994). In a longitudinal cohort study, after adjusting for sex, overall mean energy intake was higher among chocolate milk consumers than among non-consumers (Noel et al., 2013). In the aforementioned RCT that combined home deliveries of chocolate milk with SSB reduction education, there was a reduction in mean daily energy intake in the intervention group relative to control group that was primarily due to a reduction in consumption of non-milk SSBs (Albala et al., 2008).

3.3.3. The association of flavored milk intake and added sugar intake

Only one study examined the association of intake of flavored milk and consumption of added sugar (Noel et al., 2013). In the longitudinal cohort study, after adjusting for sex and total energy intake, children who consumed flavored milk had slightly lower intake of added sugars (grams/day) as compared with children who did not consume flavored milk (86 vs. 89; *p*-value 0.05) (Noel et al., 2013).

3.3.4. The association of flavored milk intake and overall milk intake

Eleven studies examined the association of flavored milk consumption with overall milk intake (Albala et al., 2008; Garey et al., 1990; Gopinath et al., 2014; Guthrie, 1977; Hanks et al., 2012; Henry et al., 2015; Henry et al., 2016; Noel et al., 2013; Quann, 2013; Wilson, 1991; Wilson, 2000). In three studies, pairing test meals with chocolate milk instead of plain milk led to significantly greater overall milk consumption among children in both school and child care settings (Garey et al., 1990; Wilson, 1991; Wilson, 2000). In a longitudinal cohort study, high frequency flavored milk intake (> 2 servings/week) was significantly associated with greater overall milk consumption (Gopinath et al., 2014). A second longitudinal cohort study also showed that chocolate milk consumers drank a greater quantity of total milk as compared to non-consumers (Noel et al., 2013). In elementary schools, providing the option of plain or chocolate milk with test meals was associated with greater milk consumption and less milk waste (Guthrie, 1977; Henry et al., 2015; Henry et al., 2016; Quann, 2013). In another experimental study in schools, students offered a healthier cafeteria food line with a flavored milk option drank more milk than students that lacked such interventions in their schools (Hanks et al., 2012). In a home-based RCT, chocolate milk deliveries and SSB reduction education led to a significant increase in overall milk intake (Albala et al., 2008).

4. Discussion

In this systematic review, evidence from longitudinal and experimental studies in school, child care, and home settings demonstrate that offering flavored milk can increase overall milk consumption among children and adolescents (Albala et al., 2008; Garey et al., 1990; Gopinath et al., 2014; Guthrie, 1977; Hanks et al., 2012; Henry et al., 2015; Henry et al., 2016; Noel et al., 2013; Quann, 2013; Wilson, 1991; Wilson, 2000) Despite flavored milk's benefits in promoting milk intake, the majority of studies also suggest that flavored milk may contribute to the intake of a greater number of overall calories (Garey et al., 1990; Guthrie, 1977; Noel et al., 2013; Wilson, 1991; Wilson, 2000). Heterogeneity of the three studies examining the association of flavored milk consumption with obesity limits the ability to quantitatively pool data and draw firm conclusions (Albala et al., 2008; Noel et al., 2013; Vanselow et al., 2009). One study showed a non-significant increase in BMI among the general population of flavored milk consumers (Vanselow et al., 2009). In another study there was a trend toward increases in BMI that were due to significant increases in lean body mass (Albala et al., 2008). A third analysis of overweight and obese children demonstrated that flavored milk intake was significantly associated with greater weight gain (Noel et al., 2013).

One other systematic review has examined how flavored milk consumption is linked to dietary intake and health outcomes. The review, conducted in 2014, had several limitations including funding support by Nestle Australia Ltd. and a low AMSTAR rating which signifies poor methodological quality (Fayet-Moore, 2016). Also, several relevant publications, including experimental studies that explore the association of flavored milk consumption and milk and energy intake among children and adolescents, were not included in the initial review (Garey et al., 1990; Gopinath et al., 2014; Guthrie, 1977; Henry et al., 2015; Henry et al., 2016).

As mentioned, the current review identified a paucity of published studies that examine how flavored milk consumption is associated with intake of overall milk and calories, and health outcomes such as obesity and metabolic syndrome. Although the majority of studies identified in this review were experimental, many had design flaws that resulted in a high risk of bias (Table 3). Moreover, while this review included one RCT, it was challenging to fully isolate the effect of flavored milk consumption on obesity because the intervention was multi-faceted (e.g., home deliveries of flavored milk were offered alongside SSB reduction education) (Albala et al., 2008). Studies suggest that exposure to added sugar at an early age increases children's sweet taste preferences and consumption of SSBs later in life (Johnson et al., 2009). To our knowledge, no intervention studies have examined how flavored milk consumption impacts intake of milk, added sugar, nutrients, and overall calories, and obesity among children who are naïve to flavored milk. This is an important area for further inquiry.

Another limitation of the studies to date is possible conflict of interest. Five of 13 studies were funded by the food and beverage industry (Gopinath et al., 2014; Guthrie, 1977; Henry et al., 2015; Henry et al., 2016; Quann, 2013), and another two studies did not disclose funding or conflict of interest (Garey et al., 1990; Wilson, 1994). Of note, all of the industry-funded studies in this review examined how flavored milk was associated with overall milk intake but failed to examine any impact on health outcomes. Previous studies in areas ranging from clinical drug trials to animal studies suggest that industry sponsorship of research is associated with bias in favor of the industry sponsor (Mandrioli and Kearns, 2016). Given these potential biases, it is important to conduct additional non industry-sponsored studies to examine how intake of flavored milk may impact obesity and related health outcomes.

While the literature showed mixed results regarding flavored milk's role in obesity, five of seven studies that explored the relationship between flavored milk and caloric intake found a positive association (Garey et al., 1990; Guthrie, 1977; Noel et al., 2013; Wilson, 1991;

Wilson, 1994). National Health and Nutrition Examination data suggest that 2–11 year old children consume 92 g of flavored milk per day which is equivalent to approximately 2.2 teaspoons of added sugar or 35 added sugar calories per day (United States Department of Agriculture, 2010). Among the youngest children (2–5 years of age), small reductions in daily caloric intake on the order of 38 cal per day could revert obesity levels in the U.S. to 1970's prevalence (Wang et al., 2013). Despite the potential contribution of flavored milk to intake of calories from added sugar, only one of the 13 studies in this review examined such information. Future studies should capture this nutritional data.

The American Heart Association and the American Academy of Pediatrics endorse flavored milk as a beverage offering (Johnson et al., 2009; Anon, 2015), citing that while SSBs, sweets, and sweetened grains are more likely to negatively impact diet quality, sweetened dairy products may boost intake of nutrients such as calcium, vitamin D, and potassium (Johnson et al., 2009; Anon, 2015). The American Academy of Pediatrics also states that while children are more likely to consume higher fat milk outside of schools, when they consume flavored milk in school settings it is more likely to be of the lower fat variety (Anon, 2015). The Robert Wood Johnson Foundation Healthy Eating Research Program convened a panel of experts to provide healthier beverage recommendations for children and adolescents (Robert Wood Johnson Foundation, n.d.). Unlike the American Heart Association and the American Academy of Pediatrics, this panel advised against consumption of flavored milk citing its contribution to increased caloric intake (Robert Wood Johnson Foundation, n.d.).

4.1. Limitations

Findings from this review are limited due to a paucity of studies, studies that employ less rigorous study designs, and possible conflict of interest due to industry funding. Although the study protocol for identification of studies was exhaustive and thorough, it is possible that we did not identify all relevant studies in the search. While we attempted to search unpublished and grey literature, we excluded unpublished studies due to concerns about the methodological quality of studies that have not been peer-reviewed. Because the characteristics (e.g., sex, race/ethnicity) of study participants were unavailable for many studies, it is also unclear how study results are generalizable to other contexts.

5. Conclusion

This systematic review suggests that while flavoring milk with added sugars may promote overall milk intake, this strategy may not be without adverse effects on caloric intake and possibly obesity for children and adolescents. Due to limited data regarding flavored milk's role in obesity, at this time there is insufficient evidence regarding the role of flavored milk in sugary drink policies. Additional rigorous studies without conflict of interest are needed to fully understand the impact of flavored milk consumption on obesity and metabolic syndrome.

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Conflict of interest statement

The authors have no conflicts of interest to disclose.

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