

Association between noncow milk beverage consumption and childhood height

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ABSTRACT

Background: Cow milk consumption in childhood has been associated with increased height, which is an important measure of children's growth and development. Many parents are choosing noncow milk beverages such as soy and almond milk because of perceived health benefits. However, noncow milk contains less protein and fat than cow milk and may not have the same effect on height.

Objective: We sought to determine whether there is an association between noncow milk consumption and lower height in childhood and assess whether cow milk consumption mediates the relation between noncow milk consumption and height.

Design: This was a cross-sectional study of 5034 healthy Canadian children aged 24–72 mo enrolled in the Applied Research Group for Kids cohort. The primary exposure was the volume of noncow milk consumption (number of 250-mL cups per day). The primary outcome was height, which was measured as height-for-age *z* score. Multivariable linear regression was used to determine the association between noncow milk consumption and height. A mediation analysis was conducted to explore whether cow milk consumption mediated the association between noncow milk consumption and height.

Results: There was a dose-dependent association between higher noncow milk consumption and lower height ($P < 0.0001$). For each daily cup of noncow milk consumed, children were 0.4 cm (95% CI: 0.2, 0.8 cm) shorter. In the mediation analysis, lower cow milk consumption only partially mediated the association between noncow milk consumption and lower height. The height difference for a child aged 3 y consuming 3 cups noncow milk/d relative to 3 cups cow milk/d was 1.5 cm (95% CI: 0.8, 2.0 cm).

Conclusions: Noncow milk consumption was associated with lower childhood height. Future research is needed to understand the causal relations between noncow milk consumption and height. *Am J Clin Nutr* 2017;106:597–602.

Keywords: noncow milk beverages, cow milk, height, childhood, pediatrics

INTRODUCTION

Height is an important indicator of children's overall nutritional status, health, and development (1–3). Cow milk is a staple for most North American children and is an important

source of dietary protein and fat—2 essential nutrients for optimal growth (4–8). A meta-analysis of intervention studies indicated that children who consumed cow milk daily were taller than those who did not (9). Milk proteins (i.e., casein and whey) and insulin-like growth factor 1 (IGF-1) in cow milk have been proposed to contribute to gains in linear growth (5, 8, 10, 11).

Many parents are replacing cow milk with noncow milk beverages such as soy, rice, or almond milk, possibly because of perceived health benefits (12–18). Lee et al. (19) identified that 12% of urban Canadian children consumed noncow milk beverages. However, noncow milk contains different proteins than cow milk and lacks IGF-1, suggesting that it may not have the same effect on height as cow milk (20–22).

Furthermore, unlike cow milk, there are no legislative requirements for standardizing the nutritional content of noncow milk under the FDA or the Food and Drug Regulations of Canada (23, 24). The protein and fat content of noncow milk beverages is highly variable. Children who consume noncow milk may receive less dietary protein and fat than children who consume cow milk (25). Understanding the relation between noncow milk consumption and height in childhood may help inform parents, clinicians, and policymakers when choosing the optimal type of milk for children.

We hypothesized that noncow milk consumption in childhood may be associated with lower childhood height. The primary objective of this study was to evaluate the association between the daily volume of noncow milk consumption and height in childhood. The secondary objective was to explore whether an

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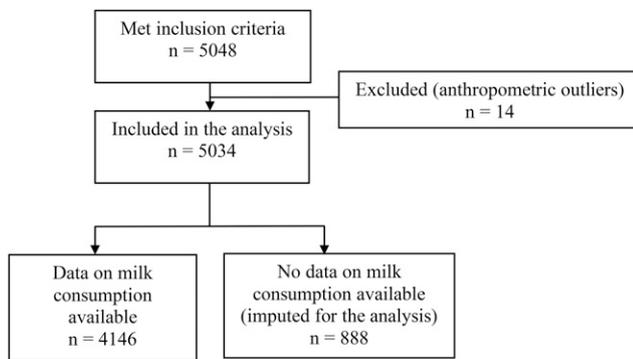


FIGURE 1 Selection of patients for the study.

association between noncow milk consumption and lower height is mediated through lower cow milk consumption.

METHODS

Study design

We conducted a cross-sectional observational study through the TARGeT Kids! (Applied Research Group for Kids) primary care practice-based research network. TARGeT Kids! is a partnership between child health researchers and primary care physicians from the University of Toronto.

Children aged 24–72 mo attending their annual well-child visits were recruited from 9 family and pediatric primary health care practices in Toronto, Canada, from December 2008 to September 2015 (26). Children were excluded from the TARGeT Kids! cohort if they had a known condition affecting

growth, chronic illnesses (excluding asthma), or severe developmental delay (**Figure 1**).

Exposures and outcomes

All questionnaires and physical measurements were collected by trained research assistants at each primary care practice with the use of standardized protocols. The primary exposure was the daily volume of noncow milk consumed (number of 250-mL cups per day), which was obtained from the following question adapted from the Canadian Community Health Survey (27): How many 250-mL cups of noncow milk (soy, rice, goat, etc.) does your child have in a typical day? The suspected mediator was the daily volume of cow milk consumed (number of 250-mL cups per day), which was obtained from the following question: How many 250-mL cups of cow milk does your child have in a typical day?

The primary outcome was height-for-age *z* score. Height was measured with the use of a calibrated stadiometer for children aged ≥ 2 y (seca model 703; measurement accuracy: $\pm 0.025\%$). The WHO growth standards were used to calculate the height-for-age *z* score. This growth standard was used because it is believed to represent optimal growth in children (28, 29).

Potential confounders that might influence the relation between the volume of noncow milk consumption and height-for-age *z* score were generated from a review of the literature and included age, sex, BMI (in kg/m^2) *z* score, maternal ethnicity, income, and maternal height. Child age and sex were collected from parental reports. Weight was measured with the use of a precision digital scale for children aged ≥ 2 y (seca model 703; measurement accuracy $\pm 0.025\%$). BMI *z* scores were calculated with the use of WHO Anthro version 3.2.2 (29). Neighborhood

TABLE 1
Characteristics of children who participated in the study¹

Characteristics	All participants (<i>n</i> = 5034)	Cow milk drinkers (<i>n</i> = 4632)	Noncow milk drinkers (<i>n</i> = 643)
Age, mo	38.7 \pm 13.7 ²	38.7 \pm 13.7	39 \pm 13.8
Sex, males, <i>n</i> (%)	2594 (52)	2388 (52)	323 (50)
BMI <i>z</i> score	0.3 (−0.4, 1.0) ³	0.3 (−0.3, 1.0)	0.2 (−0.4, 0.8)
Cups ⁴ per day			
Cow milk	1.8 \pm 1.1	2.0 \pm 1.0	1.0 \pm 1.1
Noncow milk	0.2 \pm 0.6	0.0 \pm 0.4	1.4 \pm 1.0
Height-for-age <i>z</i> score	0.1 (−0.6, 0.8)	0.2 (−0.6, 0.8)	−0.04 (−0.8, 0.7)
Maternal height	163.9 \pm 7.2	164.0 \pm 7.2	163.8 \pm 7.5
Maternal ethnicity, <i>n</i> (%)			
European	3503 (70)	3239 (70)	409 (64)
Asian	814 (16)	740 (16)	129 (20)
African	192 (4)	173 (4)	20 (3)
Mixed	250 (5)	222 (5)	54 (8)
Other	275 (5)	258 (6)	31 (5)
Neighborhood income, <i>n</i> (%)			
<\$30,000	310 (6)	275 (6)	51 (8)
\$30,000–\$79,999	3975 (79)	3675 (79)	509 (79)
\$80,000–\$150,000	679 (13)	618 (13)	71 (11)
>\$150,000	70 (1)	64 (1)	12 (2)

¹ Missing data on milk consumption were imputed for analysis for 888 children; 397 children consumed both cow and noncow milk; 156 children consumed neither cow nor noncow milk; 4235 children consumed only cow milk; and 246 children consumed only noncow milk.

² Mean \pm SD (all such values).

³ Median; IQR (all such values).

⁴ 1 cup = 250 mL.

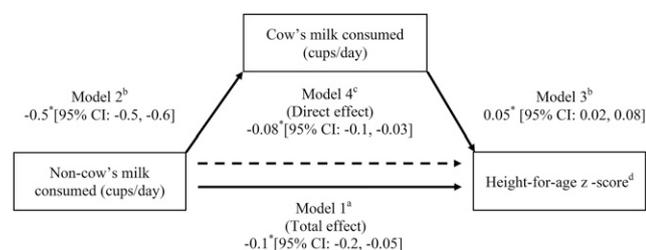


FIGURE 2 Conceptual model of the mediating effect of cow milk on the relation between noncow milk and height. ^aModel 1 (total effect) was a univariate linear regression model unadjusted for cow milk; ^bmodels 2 and 3 were univariate linear regression unadjusted models; ^cmodel 4 (direct effect) was a univariate model adjusted for cow milk. Height is expressed in z-score units. * $P < 0.001$.

income was used as an indicator for socioeconomic status and was obtained from the median after-tax neighborhood household income identified by each participant's 6-digit postal code (with the use of the Statistics Canada Postal Code Conversion File and data from the 2006 Canadian census). Maternal height was measured with the use of a stadiometer (seca model 703; measurement accuracy: $\pm 0.025\%$). Maternal ethnicity was categorized as European, Asian, African, mixed, or other (30).

Statistical analysis

Descriptive statistics, including mean, median, SD, and frequencies, were used to describe the primary exposure, outcome, and covariates (**Table 1**). Biologically implausible values for the primary outcome were removed from the analysis according to WHO recommendations (height-for-age z score ≤ -6 or ≥ 6) (29). Univariate linear regression was used to test the unadjusted relation between the daily volume of noncow milk consumed and height-for-age z score.

For the primary analysis, multivariable linear regression was used to adjust for potentially confounding factors identified in the literature as being associated with our primary outcome and exposure. These included age, sex, ethnicity, neighborhood

income, BMI z score, and maternal height. All covariates remained in the final model regardless of statistical significance (31).

For our secondary analysis we conducted a mediation analysis to explore whether the daily volume of cow milk consumption was a mediator of the relation between noncow milk consumption and height. This approach consisted of 4 different regression models (**Figure 2**). The indirect effect was calculated as the difference between the regression coefficients of the direct effect (adjusted for cow milk) and the total effect (not adjusted for cow milk) (32). The indirect effect represented the mediating effect of cow milk on the relation between noncow milk consumption and height. Bootstrap sampling (10,000 repetitions) was used to estimate a P value for the mediation effect (33–35).

Missing data for the primary outcome, primary exposure, and all covariates were $<1\%$, 16% , and $<10\%$, respectively, and the data were assumed to be missing at random. With the use of multiple imputation by chained equations, 50 different data sets were imputed and pooled together to form one complete data set (36). All imputations and analyses were conducted in R version 3.2.3 (37).

To assess the effect of multiple imputation on the results, a sensitivity analysis was conducted by repeating the primary analysis with the use of only nonimputed data. A second sensitivity analysis was performed to assess the effect of paternal height on the results by repeating the primary analysis on 827 subjects with paternal height data available.

Ethics

The research ethics boards at the Hospital for Sick Children and St. Michael's Hospital approved this study. Written consent was obtained by the parents of all participating children.

RESULTS

A total of 5048 children who met inclusion criteria and had parental consent were included in the study. Of these children,

TABLE 2
Association between volume of noncow milk consumption and height adjusted for prespecified covariates¹

Characteristics	Height-for-age z score (95% CI)	Height difference, ² cm	P value
Univariate model			
Noncow milk, cup/d	-0.1 (-0.2, -0.05)	-0.4 (-0.8, -0.2)	<0.001
Multivariate model			
Noncow milk, cup/d	-0.1 (-0.2, -0.04)	-0.4 (-0.8, -0.2)	<0.001
Age, mo	0.004 (-0.02, -0.006)	-0.02 (-0.08, 0.02)	0.001
Males	0.06 (0.0, 0.1)	0.2 (0.0, 0.4)	0.03
Maternal ethnicity			
Asian	-0.002 (-0.08, 0.08)	-0.008 (-0.3, 0.3)	0.9
African	0.4 (0.2, 0.6)	1.5 (0.8, 2.3)	<0.001
Mixed	0.002 (-0.1, 0.1)	0.008 (-0.4, 0.4)	0.9
Other	0.2 (0.06, 0.3)	0.8 (0.2, 1.1)	0.02
Maternal height, cm	0.05 (0.05, 0.05)	0.2 (0.2, 0.2)	<0.001
BMI z score	-0.01 (-0.03, 0.03)	-0.04 (-0.1, 0.1)	0.4
Neighborhood income			
>\$30,000–\$80,000	-0.1 (-0.2, 0.2)	-0.4 (-0.8, -0.8)	0.1
>\$80,000–\$150,000	0.02 (-0.1, 0.2)	0.08 (-0.4, 0.8)	0.08
>\$150,000	0.04 (-0.2, 0.3)	0.2 (0.8, 1.1)	0.6

¹ Results from the primary multivariable linear regression model ($n = 5034$).

² A height-for-age z score of -0.1 was equivalent to ~ 0.4 cm lower height for children aged 3 y.

TABLE 3
Approach for mediation by cow milk intake¹

Mediated relation	Total effect ²	Direct effect ³	Indirect effect ⁴	<i>P</i> value
Noncow milk, cups/d	-0.1 (-0.2, -0.05)	-0.08 (-0.1, -0.03)	-0.02 (-0.01, -0.04)	0.002

¹ Values are height-for-age *z* scores (95% CIs). *n* = 5034. *P* < 0.05 was considered significant.

² Total effect (*c*) = univariate linear regression model unadjusted for cow milk (mediator).

³ Direct effect (*c'*) = multivariate linear regression model adjusted for cow milk (mediator).

⁴ Indirect effect = total effect – direct effect. Obtained with the use of 10,000 bootstrap repetitions.

14 were outliers for the primary outcome and were thus excluded (Figure 1). Characteristics for children consuming cow milk and noncow milk are provided in Table 1. Participants were a mean ± SD age of 38 ± 14 mo, and 51% were males. Maternal ethnicity was primarily European (70%), and children were largely from medium- to high-income households. In total, 92% and 13% of the children consumed cow milk and noncow milk daily, respectively. Children who consumed cow milk had a mean ± SD of 2.0 ± 1.0 cups/d, whereas children who consumed noncow milk had a mean ± SD of 1.4 ± 1.0 cups/d. Children consuming each type of milk appeared similar (Table 1).

In both the univariate and primary multivariate analyses there was a dose-dependent association between higher noncow milk consumption and lower height. Each daily cup of noncow milk consumed was associated with a 0.1-lower height-for-age *z* score (95% CI: 0.05, 0.2; *P* < 0.001) or 0.4-cm lower height/cup (95% CI: 0.2, 0.8 cm) for children aged 3 y (Table 2). The height difference between children aged 3 y who drank 0 cups noncow milk/d relative to 3 cups/d was 0.3 height-for-age *z*-score units (95% CI: 0.1, 0.5) or 1.2 cm (95% CI: 0.4, 1.8 cm).

In the secondary mediation analysis there was a 0.5-cup lower daily cow milk intake (95% CI: 0.5, 0.6 cups; *P* < 0.001) for each daily cup of noncow milk consumed. Each cup of cow milk was associated with a 0.05 higher height-for-age *z* score (95% CI: 0.02, 0.08; *P* < 0.001) or 0.2-cm higher height per cup (95% CI: 0.08, 0.3 cm) for children aged 3 y. When adjusted for cow milk consumption, noncow milk consumption remained negatively associated with height [0.08 lower height-for-age *z* score (95% CI: 0.03, 0.1; *P* < 0.001) or 0.3-cm lower height/cup (95% CI: 0.1, 0.4 cm) of noncow milk for children aged 3 y] (Figure 2, Table 3). Cow milk consumption partially mediated the association between noncow milk and height. A 0.02-lower height-for-age *z* score (95% CI: 0.01, 0.04; *P* < 0.002) or 0.08-cm lower height/cup (95% CI: 0.04, 0.2 cm) of noncow milk could be explained by a reduction in cow milk (indirect effect). For example, a 3-y-old child who consumed 3 cups of noncow milk and 0 cups of cow milk had a lower height-for-age *z* score of 0.4 (95% CI: 0.2, 0.5) or ~1.5-cm lower height (95% CI: 0.8, 2.0 cm) relative to a child of the same age who consumed 3 cups of cow milk and 0 cups of noncow milk (Figure 3).

Repeating the primary analysis with the use of only non-imputed data did not change the results. Including only children with paternal height data produced similar findings but with wider CIs because of the smaller sample size.

DISCUSSION

We have identified a dose-dependent association between higher consumption of noncow milk and lower height in childhood. For the average child, each daily cup of noncow milk consumed was

associated with a 0.4-cm lower height. This relation was only partially mediated by lower cow milk consumption. Children aged 3 y who consumed 3 cups noncow milk/d relative to 3 cups cow milk/d were, on average, 1.5 cm shorter. This height difference was similar to the difference between the major percentile lines in the WHO growth charts (29).

To our knowledge, the association between higher consumption of noncow milk and lower childhood height has not been reported. However, the association between higher consumption of cow milk and increased height has been described previously. Similar to our study, DeBoer et al. (4) also identified a 0.06 higher height-for-age *z* score for each cup of cow milk consumed. In addition, a meta-analysis of intervention studies identified similar gains in height among children assigned to consume cow milk (9). Although the biological mechanism for this effect is unclear, it has been hypothesized that milk proteins (i.e., casein and whey) and IGF-1 in cow milk may contribute to height (9, 38, 39). Cow milk protein has also been shown to stimulate serum IGF-1 concentrations that may increase height via the growth hormone IGF-1 axis, which promotes cellular growth in bones and in other body tissues (8, 39–41).

Several studies have identified that cow milk-avoidant children appear to be shorter than children who consume cow milk (22). It has been hypothesized that such children may not receive sufficient protein or calories to support optimal growth (12, 20, 25). Alternatively, the reason for milk avoidance such as illness or food allergy has also been suggested as possible mechanisms (15, 20, 22). Hoppe et al. (39) investigated total protein intake, serum IGF-1, and height and found that children who consumed

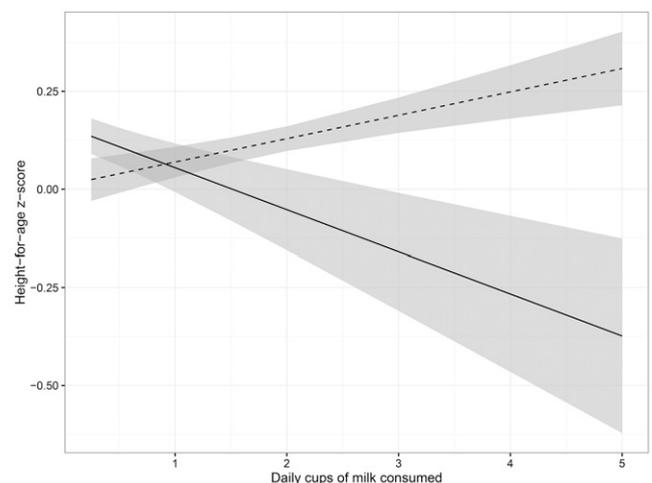


FIGURE 3 Adjusted association between milk consumption and height. Multivariate linear regression was adjusted for age, sex, maternal ethnicity, maternal height, BMI *z* scores, and neighborhood income. Gray areas are 95% CIs. **P* < 0.001.

more plant-based protein (e.g., legumes), which do not contain IGF-1, were slightly shorter (by 0.1 cm) and had lower concentrations of IGF-1 than children who consumed animal-based protein and milk, which may explain why the association between higher noncow milk intake and lower height was only partially mediated through lower cow milk intake.

Many noncow milk beverages are marketed and sold as milk products for children. Although the nutritional content of cow milk is standardized by the FDA and the Food and Drug Regulations of Canada (23, 24), noncow milk is not subject to the same standards. The USDA MyPlate and Canadian Food Guide have acknowledged that unfortified milk alternatives do not provide the same energy, protein, or vitamins and minerals found in cow milk (21, 25, 42). For example, 2 cups of cow milk contain 16 g protein, which is 70% of the daily protein requirement for children aged 3 y. Two cups of almond milk, on the other hand, contains 4 g protein, which is only 25% of the daily protein requirement for children aged 3 y who may not be receiving sufficient dietary protein from other sources to support optimal growth.

Standardization of the nutritional content of noncow milk may assist parents in choosing between milk beverages of equal nutritional content. Alternatively, improved front-of-package labeling to indicate micronutrient fortification (including calcium and vitamin D) or whether the milk beverage provides a sufficient source of protein for children would assist parents in making informed decisions about the appropriate choice of milk for their children.

Strengths of this study include a relatively large multicultural sample ($n = 5034$) of healthy urban preschool-aged children. Data on milk consumption anthropometric measurements and numerous clinically relevant factors such as maternal height, ethnicity, and family income allowed for the adjustment of potential confounders, and the magnitude of the association between cow milk consumption and height was consistent with other studies that have suggested the generalizability of our findings (4, 9). Furthermore, we used a sophisticated analytic approach that included multiple imputations to address missing data and a rigorous stepwise mediation analysis to explore the relation between cow milk consumption and the primary effect.

Limitations of this study include the cross-sectional design for which we could determine associations but not causal relations. Questionnaire data about milk intake may be subject to measurement error or recall bias. Height, although measured with the use of standardized techniques, may be subject to measurement error given the young age of this population. Although we adjusted for numerous potential confounding variables, residual confounding remains a possibility. For example, we were unable to account for other dietary factors that may contribute to height because of data limitations. Noncow milk beverages vary in nutritional content, and we could not evaluate which noncow milk beverages most influenced the observed relation (e.g., soy and goat milk beverages tend to have higher protein content than almond or rice milk beverages). Adjusting for paternal height would have been desirable, but we had limited data on this variable. However, repeating the primary analysis with children who had paternal height data resulted in similar findings. In addition, although the population was ethnically diverse, it may not be representative of all urban North American children.

Although cow milk consumption has been associated with increased childhood height, noncow milk consumption seems to

be associated with lower childhood height. Each daily cup of noncow milk consumed was associated with a 0.4-cm lower childhood height. This relation was only partially mediated by a 0.5-cup lower cow milk consumption for each cup of noncow milk consumed. Our findings may be important for parents, dietitians, and physicians when considering the optimal type of milk for children to consume. Future research is needed to understand which noncow milk beverages are most responsible for this association as well as understanding the causal relations between noncow milk consumption and childhood height.

The authors' responsibilities were as follows—M-EM and JLM: designed the study, performed the statistical analyses, composed the draft of the manuscript, and were responsible for the final content of the manuscript; GJL, ML, and CSB: assisted in the research design and reviewed and revised the manuscript; GL and YC: assisted in the statistical analyses and reviewed and revised the manuscript; and all authors: read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

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