Association between non-cow’s milk beverage consumption and childhood height

Marie-Elssa Morency, Catherine S. Birken, Gerald Lebovic, Yang Chen, Mary L’Abbé, Grace J. Lee, and Jonathon L. Maguire

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Title Page

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Non-cow’s milk consumption and childhood height

Study Registration:
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Abbreviations:

- BMI: Body Mass Index
- IGF-I: Insulin-like-growth factor I
- WHO: World Health Organization
- SD: Standard Deviation
- CI: Confidence Interval
- IQR: Interquartile Range
Abstract

Background

Cow’s 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 non-cow’s milk beverages like soy and almond milk because of perceived health benefits. However, non-cow’s milk contains less protein and fat than cow’s milk and may not have the same effect on height.

Objective

The primary objective was to determine whether there is an association between non-cow’s milk consumption and lower height in childhood. The secondary objective was to assess whether cow’s milk consumption mediates the relationship between non-cow’s milk consumption and height.

Design

This was a cross-sectional study of healthy Canadian children ages 24-72 months enrolled in the TARGetKids! cohort (The Applied Research Group for Kids) were included. The primary exposure was volume of non-cow’s milk consumption (250 mL cups/day). The primary outcome was height, measured as height-for-age z-score. Multivariable linear regression was used to determine the association between non-cow’s milk consumption and height. A mediation analysis was conducted to explore whether cow’s milk consumption mediated the association between non-cow’s milk consumption and height.

Results

5034 children were included in the study. There was a dose dependent association between higher non-cow’s milk consumption and lower height (P <0.0001). For each daily cup of non-
cow’s milk consumed, children were 0.4cm (95% CI: 0.2, 0.8cm) shorter. In the mediation analysis, lower cow’s milk consumption only partially mediated the association between non-cow’s milk consumption and lower height. The height difference for a 3-year-old consuming 3 cups of non-cow’s milk relative to 3 cups of cow’s milk was 1.5 cm (95% CI: 0.8, 2.0cm).

Conclusions

Non-cow’s milk consumption was associated with lower childhood height. Future research is needed to understand the causal relationships between non-cow’s milk consumption and height.

Key words: non-cow’s milk beverages, cow’s milk, height, childhood, paediatrics
**Introduction**

Height is an important indicator of children’s overall nutritional status, health and development (1-3). Cow’s milk is a staple for most North American children and is an important source of dietary protein and fat, two essential nutrients for optimal growth (4-8). A meta-analysis of intervention studies identified that children consuming cow’s milk daily were taller than children not consuming cow’s milk (9). Milk proteins (i.e., casein and whey) and insulin-like growth factors (IGF-1) in cow’s milk have been proposed to contribute to gains in linear growth (5, 8, 10, 11).

Many parents are replacing cow’s milk with non-cow’s milk beverages such as soy, rice or almond milk possibly due to perceived health benefits (12-18). A recent paper identified that 12% of urban Canadian children were consuming non-cow’s milk beverages (19). However, non-cow’s milk contains different proteins than cow’s milk and lacks IGF-1, suggesting that it may not have the same effect on height as cow’s milk (20-22).

Further, unlike cow’s milk, there are no legislative requirements for nutritional content standardization of non-cow’s milk under the Food and Drug Administration of the United States or the Food and Drug Regulations of Canada (23, 24). The protein and fat content of non-cow’s milk beverages are highly variable. Children who consume non-cow’s milk may receive less dietary protein and fat than children who consume cow’s milk (25). Understanding the relationship between non-cow’s milk consumption and height in childhood may help inform parents, clinicians and policy makers when choosing the optimal type of milk for children.

We hypothesized that non-cow’s milk consumption in childhood may be associated with lower childhood height. The primary objective of this study was to evaluate the association between daily volume of non-cow’s milk consumption and height in early childhood. The
secondary objective was to explore whether an association between non-cow’s milk consumption and lower height is mediated through lower cow’s milk consumption.
Subjects and Methods

Study Design

We conducted a cross-sectional observational study through the TARGet Kids! primary care practice based research network. TARGet Kids! is a partnership between child health researchers and primary care physicians from the Faculty of Medicine, Department of Pediatrics and the Department of Family and Community Medicine at the University of Toronto.

Children ages 24-72 months attending their annual well-child visits were recruited from nine family and pediatric primary healthcare practices in Toronto, Canada from December 2008 to September 2015 (26). Children were excluded from the TARGetKids! 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 using standardized protocols. The primary exposure was daily volume of non-cow’s milk consumed (250mL cups/day) obtained from the following question adapted from the Canadian Community Health Survey (27): “How many 250mL cups of non-cow’s milk (soy, rice, goat etc.) does your child have in a typical day?”. The suspected mediator was daily volume of cow’s milk consumed (250mL cups/day), which was measured from the following question: “How many 250mL cups of cow’s milk does your child have in a typical day?”.

The primary outcome was height-for-age z-score. Height was measured using a calibrated stadiometer for children two years of age or older and a length board for children younger than two years (Seca, model 703, measurement accuracy +/- 0.025%; Seca). The World Health
Organization (WHO) growth standards were used to calculate height-for-age z-score. This growth standard was used as it is believed to represent optimal growth in children (28, 29).

Potential confounders which might influence the relationship between volume of non-cow’s milk consumption, and height-for-age z-score were generated from a review of the literature and included: age, sex, body mass index (BMI) z-score, maternal ethnicity, income, and maternal height. Child age, and sex were collected by parent report. Weight was measured using a precision digital scale for children two years or older (Seca model 703, measurement accuracy +/- 0.025%; Seca). BMI was calculated using measured weight (kg) / height (metres) squared. BMI z-scores were calculated using the World Health Organization (WHO) Anthro (version 3.2.2) (29). Neighborhood 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 (using the Statistics Canada Postal Code Conversion File and data from the 2006 Canadian census). Maternal height was measured using a stadiometer (Seca model 703, measurement accuracy +/- 0.025%; Seca). 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 (summarized in Table 1). Biologically implausible values for the primary outcome were removed from the analysis according to the WHO recommendations (height-for-age z-score ≤ -6 or greater than or equal to +6) (29). Univariate linear regression was used to test the unadjusted relationship between daily volume of non-cow’s 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 daily volume of cow’s milk consumption was a mediator of the relationship between non-cow’s milk consumption and height. This approach consisted of four different regression models (Figure 2). The indirect effect was calculated as the difference between the regression coefficients of the direct effect (adjusted for cow’s milk) and the total effect (not adjusted for cow’s milk) (32). The indirect effect represents the mediating effect of cow’s milk on the relationship between non-cow’s 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 of the covariates were <1%, 16% and < 10% respectively and the data were assumed to be missing at random. Using multiple imputation by chained equations, 50 different datasets were imputed and pooled together to form one complete dataset (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 using only non-imputed data. A second sensitivity analysis was performed to assess the affect 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 at St. Michael’s Hospital, Toronto, Canada approved this study. Written consent was obtained by the parents of all participating children.
Non-cow’s milk consumption and childhood height

Results

A total of 5048 children who met inclusion criteria and had parental consent were included in the study. Of these, 14 children were outliers for the primary outcome and were excluded (Figure 1). Baseline characteristics for children consuming cow’s milk and non-cow’s milk are provided in Table 1. Participants were on average 38 months of age (standard deviation [SD]14) and 51% were male. Maternal ethnicity was primarily European (70%) and children were largely from medium to high income households. 92% of children consumed cow’s milk and 13% consumed non-cow’s milk daily. Children who consumed cow’s milk had on average 2.0 cups (SD 1.0) per day while children who consumed non-cow’s milk had 1.4 (SD 1.0) cups per day. Children consuming each type of milk appeared similar (Table 1).

In both the univariate analysis and the primary multivariate analysis, there was a dose dependent association between higher non-cow’s milk consumption and lower height. Each daily cup of non-cow’s milk consumed was associated with a 0.1 (95% confidence interval [CI]: 0.05, 0.2, P<0.001) lower height-for-age z-score or 0.4cm (95% CI: 0.2, 0.8cm) lower height per cup for a 3-year-old child (Table 2). The height difference between a child who drank 0 cups of non-cow’s milk daily relative to 3 cups daily, was 0.3 (95% CI: 0.1, 0.5) height-for-age z-score units or 1.2cm (95% CI: 0.4, 1.8cm) for a 3-year-old-child.

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

Repeating the primary analysis using only non-imputed data did not change the results. Including only children with paternal height data produced similar findings but with wider confidence intervals owing to the smaller sample size.
Non-cow’s milk consumption and childhood height

Discussion

We have identified a dose dependent association between higher consumption of non-cow’s milk and lower height in childhood. For the average child, each daily cup of non-cow’s milk consumed was associated with a 0.4cm lower height. This relationship was only partially mediated by lower cow’s milk consumption. A 3-year-old child consuming 3 cups of non-cow’s milk relative to 3 cups of cow’s milk was on average 1.5cm shorter. This height difference is similar to the difference between the major percentile lines on the WHO growth charts (29).

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

Several studies have identified that cow’s milk avoidant children appear to be shorter than children who consume cow’s 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 have also been suggested as possible mechanisms (15, 20, 22). Hoppe et al. (2004) investigated total protein intake, serum IGF-1 and height and found that children who consumed more plant-based protein (i.e. legumes), which do
not contain IGF-1, were slightly shorter (by 0.1cm) and had lower levels of IGF-1 compared to children who consumed animal-based protein and milk (39). This may provide an explanation for why the association between higher non-cow’s milk intake and lower height was only partially mediated through lower cow’s milk intake.

Many non-cow milk beverages are marketed and sold as milk products for children. While the nutritional content of cow’s milk is standardised by the Food and Drug Administration of the United States and the Food and Drug Regulations of Canada (23, 24), non-cow’s milk is not subject to the same standards. The United States Department of Agriculture MyPlate and the Canadian Food Guide have acknowledged that unfortified milk alternatives do not provide the same energy, protein, or vitamins and minerals found in cow’s milk (21, 25, 42). For example, 2 cups of cow’s milk contains 16 grams of protein which is 100% of the daily protein requirement for a 3-year-old child. Two cups of almond milk beverage, on the other hand, contains 4 grams of protein which is only 25% of the daily protein requirement for a 3-year-old who may not be receiving sufficient dietary protein from other sources to support optimal growth.

Standardization of the nutritional content of non-cow’s 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 multi-cultural sample (n = 5034) of healthy urban preschool children. Data on milk consumption and anthropometric measurements, as well as data on numerous clinically relevant factors such maternal height, ethnicity and family income allowed for adjustment of potential confounders and the magnitude of the association
between cow’s milk consumption and height was consistent with other studies suggesting
generalizability of our findings (4, 9). Further, we used a sophisticated analytical approach
including multiple imputation to address missing data and a rigorous step-wise mediation
analysis to explore the relationship between cow’s milk consumption and the primary effect.

Limitations of this study include the cross-sectional design for which we cannot
determine causal relationships, only associations. Questionnaire data about milk intake may be
subject to measurement error or recall bias. Height, although measured using standardized
techniques, may also 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 which
may contribute to height due to data limitations. Non-cow’s milk beverages vary in nutritional
content and we were unable to evaluate which non-cow milk beverages most influenced the
observed relationship (i.e. soy and goat milk beverages tend to have higher protein content than
almond or rice milk beverages for example). Adjustment 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. Also, while the population was
ethnically diverse, it may not be representative of all urban North American children.

While cow’s milk consumption has been associated with increased childhood height,
non-cow’s milk consumption appears to be associated with lower childhood height. Each daily
cup of non-cow’s milk consumed was associated with a 0.4cm lower childhood height. This
relationship was only partially mediated by a 0.5 cup lower cow’s milk consumption for each
cup of non-cow’s milk consumed. Our findings may be important for parents, dieticians and
physicians when considering the optimal type of milk for children to consume. Future research is
needed to understand which non-cow’s milk beverages are most responsible for this association as well as understanding the causal relationships between non-cow’s milk consumption and childhood height.
Acknowledgments


Potential conflict of interest: None to declare

Contributors’ statement:
MEM and JLM designed the research study, performed statistical analyses, composed the draft and final manuscript content.
GJL, ML and CSB assisted in the research design, and reviewed and revised the manuscript.
GL and YC assisted with performing statistical analyses and reviewed and revised the manuscript.
All authors read and approved the manuscript.
References


Non-cow’s milk consumption and childhood height


### Table 1: Baseline characteristics of children who participated in the study

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>All participants(^1,2,3,4) (n = 5034)</th>
<th>Cow milk drinkers(^4) (n = 4632)</th>
<th>Non-cow milk drinkers(^5) (n = 643)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, month, mean ± SD(^6)</td>
<td>38.7 ± 13.7</td>
<td>38.7 ± 13.7</td>
<td>39 ± 13.8</td>
</tr>
<tr>
<td>Sex, male no. (%)</td>
<td>2594 (52)</td>
<td>2388 (52)</td>
<td>323 (50)</td>
</tr>
<tr>
<td>BMI(^7) z-score median(IQR)(^8)</td>
<td>0.3 (-0.4, 1.0)</td>
<td>0.3 (-0.3, 1.0)</td>
<td>0.2 (-0.4, 0.8)</td>
</tr>
<tr>
<td>No. of cups(^9) per day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow’s milk</td>
<td>1.8 ± 1.1</td>
<td>2.0 ± 1.0</td>
<td>1.0 ± 1.1</td>
</tr>
<tr>
<td>Non-cow’s milk</td>
<td>0.2 ± 0.6</td>
<td>0.0 ± 0.4</td>
<td>1.4 ± 1.0</td>
</tr>
<tr>
<td>Height-for-age z-score, median(IQR)</td>
<td>0.1 (-0.6, 0.8)</td>
<td>0.2 (-0.6, 0.8)</td>
<td>-0.04 (-0.8, 0.7)</td>
</tr>
<tr>
<td>Maternal height</td>
<td>163.9 ± 7.2</td>
<td>164.0 ± 7.2</td>
<td>163.8 ± 7.5</td>
</tr>
<tr>
<td>Maternal Ethnicity no. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td>3503 (70)</td>
<td>3239 (70)</td>
<td>409 (64)</td>
</tr>
<tr>
<td>Asian</td>
<td>814 (16)</td>
<td>740 (16)</td>
<td>129 (20)</td>
</tr>
<tr>
<td>African</td>
<td>192 (4)</td>
<td>173 (4)</td>
<td>20 (3)</td>
</tr>
<tr>
<td>Mixed</td>
<td>250 (5)</td>
<td>222 (5)</td>
<td>54 (8)</td>
</tr>
<tr>
<td>Other</td>
<td>275 (5)</td>
<td>258 (6)</td>
<td>31 (5)</td>
</tr>
<tr>
<td>Neighborhood Income (no. %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; $30,000</td>
<td>310 (6)</td>
<td>275 (6)</td>
<td>51 (8)</td>
</tr>
<tr>
<td>$30,000 to $79,999</td>
<td>3975 (79)</td>
<td>3675 (79)</td>
<td>509 (79)</td>
</tr>
<tr>
<td>$80,000 to $150,000</td>
<td>679 (13)</td>
<td>618 (13)</td>
<td>71 (11)</td>
</tr>
<tr>
<td>&gt; $150,000</td>
<td>70 (1)</td>
<td>64 (1)</td>
<td>12 (2)</td>
</tr>
</tbody>
</table>

---

\(^1\) 888 children with missing data on milk consumption (imputed for analysis)

\(^2\) 397 children consumed both cow’s milk and non-cow’s milk

\(^3\) 156 children consumed neither cow’s milk or non-cow’s milk

\(^4\) 4235 children only consumed cow’s milk

\(^5\) 246 children only consumed non-cow’s milk

\(^6\) SD = standard deviation

\(^7\) BMI = body mass index

\(^8\) IQR = interquartile range

\(^9\) 1 cup = 250mL
### Table 2: Association between volume of total non-cow’s milk consumption and height adjusted for pre-specified covariates

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Height-for-age z-score (95% CI)</th>
<th>Height difference (cm)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Univariate Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-cow’s milk</td>
<td>-0.1 (-0.2, -0.05)</td>
<td>-0.4 (-0.8, -0.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(cup/day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multivariate Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-cow’s milk</td>
<td>-0.1 (-0.2, -0.04)</td>
<td>-0.4 (-0.8, -0.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(cup/day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (month)</td>
<td>0.004 (-0.02, -0.006)</td>
<td>-0.02 (-0.08, 0.02)</td>
<td>0.001</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>0.06 (0.0, 0.1)</td>
<td>0.2 (0.0, 0.4)</td>
<td>0.03</td>
</tr>
<tr>
<td>Maternal ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>-0.002 (-0.08, 0.08)</td>
<td>-0.008 (-0.3, 0.3)</td>
<td>0.9</td>
</tr>
<tr>
<td>African</td>
<td>0.4 (0.2, 0.6)</td>
<td>1.5 (0.8, 2.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mixed</td>
<td>0.002 (-0.1, 0.1)</td>
<td>0.008 (-0.4, 0.4)</td>
<td>0.9</td>
</tr>
<tr>
<td>Other</td>
<td>0.2 (0.06, 0.3)</td>
<td>0.8 (0.2, 1.1)</td>
<td>0.02</td>
</tr>
<tr>
<td>Maternal height (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>-0.002 (-0.08, 0.08)</td>
<td>-0.008 (-0.3, 0.3)</td>
<td>0.9</td>
</tr>
<tr>
<td>African</td>
<td>0.4 (0.2, 0.6)</td>
<td>1.5 (0.8, 2.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mixed</td>
<td>0.002 (-0.1, 0.1)</td>
<td>0.008 (-0.4, 0.4)</td>
<td>0.9</td>
</tr>
<tr>
<td>Other</td>
<td>0.2 (0.06, 0.3)</td>
<td>0.8 (0.2, 1.1)</td>
<td>0.02</td>
</tr>
<tr>
<td>z-BMI (z-score)</td>
<td>-0.01 (-0.03, 0.03)</td>
<td>-0.04 (-0.1, 0.1)</td>
<td>0.4</td>
</tr>
<tr>
<td>Neighborhood income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; $30,000</td>
<td>-0.1 (-0.2, 0.2)</td>
<td>-0.4 (-0.8, -0.8)</td>
<td>0.1</td>
</tr>
<tr>
<td>$ 80,000 to $150,000</td>
<td></td>
<td></td>
<td>0.08</td>
</tr>
<tr>
<td>&gt;$150,000</td>
<td>0.04 (-0.2, 0.3)</td>
<td>0.2 (0.8, 1.1)</td>
<td>0.6</td>
</tr>
</tbody>
</table>

1 Results from the primary multi-variable linear regression model (n = 5034)  
2 For a child 3 years of age with a height-for-age z-score of -0.1 is equivalent to approximately 0.4 cm lower height.
Table 3: Approach for mediation by cow’s milk intake

<table>
<thead>
<tr>
<th>Mediated relationship</th>
<th>Total effect (^2) (95% CI)</th>
<th>Direct effect (^3) (95% CI)</th>
<th>Indirect effect (^4) (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height-for-age z-score</td>
<td>-0.1 (-0.2, -0.05)</td>
<td>-0.08 (-0.1, -0.03)</td>
<td>-0.02 (-0.01, -0.04)</td>
<td>0.002</td>
</tr>
<tr>
<td>Non-cow’s milk (cups/day)</td>
<td>(^*)P&lt;0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Population included in analysis (N = 5034)

\(^2\) Total effect (c) = univariate linear regression model un-adjusted for cow’s milk (mediator)

\(^3\) Direct effect (c’) = multivariate linear regression model adjusted for cow’s milk (mediator)

\(^4\) Indirect effect = total effect – direct effect

\(^5\) Indirect effect confidence interval obtained by bootstrap 10,000 repetitions
Figure 1: Selection of patients for the study

Figure 2: Conceptual model of the mediating effect of cow’s milk on the relationship between non-cow’s milk and height.

a Model 1 (Total effect) = univariate linear regression model un-adjusted for cow’s milk  
b Model 2 and Model 3 = univariate linear regression un-adjusted models  
c Model 4 (Direct effect) = univariate model adjusted for cow’s milk  
d Height in z-score units  
*Statistically significant, P<0.001

Figure 3: Adjusted association between milk consumption and height*.  
1Multivariate linear regression adjusted for age, sex, maternal ethnicity, maternal height, z-BMI, and neighborhood income *Statistically significant, P<0.001. Grey areas = 95% confidence intervals

Legend for Figure 3: