Association Between Meat and Meat-Alternative Consumption and Iron Stores in Early Childhood

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The association between meat and meat alternatives consumption and iron stores in early childhood

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Contributor's Statement

Kelly Anne Cox, Cornelia M. Borkhoff: Ms. Cox and Dr. Borkhoff conceptualized and designed the study, carried out the analysis, drafted the initial manuscript, and approved the final version of the manuscript.

Patricia C. Parkin: Dr. Parkin conceptualized and designed the study, critically reviewed the manuscript, and approved the final version of the manuscript.

Laura N. Anderson, Yang Chen: Dr. Anderson and Mr. Chen provided feedback on the analyses, critically reviewed the manuscript, and approved the final version of the manuscript.

Catherine S. Birken, Jonathon L. Maguire, and Colin Macarthur: Drs. Birken, Maguire and Macarthur designed the data collection instruments, supervised the data collection, critically reviewed the manuscript, and approved the final version of the manuscript.

All authors agree to be accountable for all aspects of the work.

ABSTRACT

Objective: To prevent iron deficiency, 2014 Canadian recommendations for healthy term infants from six to 24 months recommend iron-rich complementary foods such as meat/meat alternatives two or more times a day. The purpose of our study was to evaluate the association between meat/meat alternatives consumption and iron status in young children and the association between red meat consumption and iron status among children meeting recommendations.

Methods: Healthy children, ages 12-36 months, were recruited. A cross-sectional study was conducted. Meat/meat alternatives consumption was measured using the NutriSTEP® questionnaire. Adjusted multivariable regression analyses were used to evaluate an association between meat consumption and serum ferritin, and iron deficiency (serum ferritin <14 µg/L).

Results: 1043 children were included. 73% of children met the recommended daily intake of meat/meat alternatives and 66% ate red meat in the past three days. Eating meat/meat alternatives was not associated with serum ferritin (0.13 µg/L, 95% CI:-0.05 to 0.31, $P=0.16$), but was associated with a decreased odds of iron deficiency (odds ratio=0.97, 95% CI:0.94 to 0.99, $P=0.03$). Associations between red meat consumption and iron status were not statistically significant. Statistically significant covariates associated with increased odds of iron deficiency included longer breastfeeding duration, daily cow's milk intake >2 cups, and a higher zBMI.

Discussion: Daily cow's milk intake > 2 cups, longer breastfeeding duration, and a higher zBMI are modifiable risk factors associated with iron deficiency. Eating meat according to recommendations may be a promising additional target for the prevention of iron deficiency in early childhood.

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What's New

Higher meat or meat alternatives consumption among 12- to 36-month-old children modestly but significantly reduced the risk for iron deficiency. Our findings highlight that when combined with other healthy feeding practices, eating meat according to current recommendations may prevent iron deficiency in early childhood.

INTRODUCTION

Early childhood is a critical period in human development.¹ Iron deficiency anemia is known to be associated with delays in early childhood cognitive development which may be irreversible, and has been associated with long-term educational, cognitive and emotional impairments.² Iron deficiency peaks in prevalence during the toddler years (1-3 years) largely due to nutritional factors.² In Canada, studies suggest a prevalence of iron deficiency amongst young children of 12% or higher, and a prevalence of 1.5% or higher for iron deficiency anemia.³ This is similar to the United States, where the prevalence of iron deficiency among 1-2 year olds is 14% .^{4,5} Diet and feeding practices established in early childhood have the potential to prevent iron deficiency and optimize human development.

In 2003, the World Health Organization (WHO) and the Pan American Health Organization (PAHO) published unified, scientifically-based guiding principles for complementary feeding of the breastfed child.⁶ The guidelines recommend introducing complementary foods at 6 months of age while continuing to breastfeed, and that “meat, poultry, fish or eggs should be eaten daily, or as often as possible” to ensure the nutrient needs of the child.⁶

There has been increasing interest in examining the role of meat as a first complementary food with respect to iron status in infancy.⁷ However, the results of observational and randomized trials of the relationship between meat and iron status in early childhood have been inconsistent.⁸⁻¹⁸

In Canada, screening for iron deficiency is not recommended.¹⁹ However, social policies, such as maternity and parental leave benefits for up to one year,²⁰ support breastfeeding and other healthy feeding practices. Breastfeeding initiation is high (90%), more than half of women

report exclusive breastfeeding at three months and any breastfeeding at six months, and complementary foods are introduced on average at 4.8 months.²¹ In 2014, Health Canada, Canadian Paediatric Society, Dietitians of Canada, and Breastfeeding Committee for Canada published a joint statement for healthy term infants from six to 24 months of age.¹⁹ Introduction of complementary feeding is recommended at about six months of age, parents and caregivers are advised to “first introduce iron-rich meat and meat alternatives, and iron-fortified cereals”, and to offer iron-rich foods two or more times a day.¹⁹ Meat is emphasized as an important source of heme-iron that is highly bioavailable compared with non-heme iron sources found in meat alternatives (e.g., legumes) and iron-fortified cereals.¹⁹

In the United States, breastfeeding initiation is at 79%, and 49% of infants are breastfeeding at six months of age.²² The American Academy of Pediatrics similarly recommends iron-rich first foods, although no specific number of servings are suggested; instead, it focuses on the total amount of iron required in the diet (7 mg/day for a 1-3 year old).²

The relationship between the consumption of meat and meat alternatives and the iron status of young children has not been previously examined in Canadian children. The purpose of this study was to evaluate the association between meat and meat alternatives consumption and iron status in young children. For our secondary objective we sought to determine the association between red meat consumption and iron status among children meeting current Canadian recommendations for meat consumption.

METHODS

Participants

This was a cross-sectional study of healthy urban children, ages 12 to 36 months who attended scheduled health supervision visits at a TARGetKids! participating pediatric or family medicine primary care practice in Toronto, Canada between March 2008 and March 2015. TARGetKids! is a primary care practice-based research network set in Toronto, Canada (www.targetkids.ca).²³ Study participants were recruited by research personnel embedded in 9 participating clinics. Sociodemographic, lifestyle and nutritional information were collected during a scheduled visit through a standardized parent-completed survey instrument based on the Canadian Community Health Survey.²⁴ Laboratory tests were also collected at these visits; for children with more than one visit, the first visit with serum ferritin testing was included in the analysis.

Exclusion criteria were: chronic conditions except asthma, severe developmental delay, impaired growth, and families unable to communicate in English. We restricted the ages to 12–36 months because iron deficiency is most prevalent during this period.³ Children with elevated C-reactive Protein ($\geq 10\text{mg/L}$), a marker of inflammation, were excluded because it can distort serum ferritin levels.²⁵ Children receiving iron supplementation or a daily multivitamin with iron were excluded. We also excluded children with missing data on the exposure variables or outcome variable.

Consent was obtained from parents and ethical approval was granted from the Research Ethics Boards at The Hospital for Sick Children and St. Michael's Hospital.

Exposure Variables

Parents completed the NutriSTEP® questionnaire (Nutrition Screening Tool for Every Preschooler)²⁶ to assess our main predictor variable, meat or meat alternatives consumption. The NutriSTEP® is a parent-administered 17-item nutrition screening questionnaire. Validity has been examined with a registered dietitian assessment (based on clinical assessment, 3 days of dietary recall and anthropometric measurements), with area under the receiver operating characteristic curve >73%; reliability has an intra-class correlation coefficient of 0.89. Meat or meat alternatives consumption was determined through parental response to the question: “My child usually eats meat, fish, poultry, or alternatives: (alternatives can be eggs, peanut butter, tofu, nuts, and cooked beans, chickpeas and lentils) a) More than 2 times a day; b) 2 times a day; c) Once a day; d) A few times a week; e) Not at all.” The frequency of meat consumption was treated as a continuous variable, and recoded to reflect weekly meat consumption: 0=Not at all; 3=A few times a week; 7=Once a day; 14=2 times a day; and, 21=More than 2 times a day. Those who answered *more than 2 times a day* and *2 times a day* were coded as eating meat or meat alternatives according to current Canadian recommendations (yes/no).

Our second predictor variable was red meat consumption. This was determined through parental response to the following question: “Please specify your child’s diet in the past 3 days. Please check all that apply.” Those who checked *red meat (beef, veal, pork, lamb, etc.)* were coded as eating red meat (yes/no).

Outcome Variables

Our main outcome variable was iron status. Serum ferritin has been described as the best indicator of iron stores in the absence of inflammation.²⁷ The American Academy of Pediatrics notes that hemoglobin concentration as a measure of iron status lacks specificity and sensitivity,

and recommends measurement of serum ferritin and C-reactive protein.² We measured serum ferritin using a Roche Modular platform (Roche Diagnostics, <http://www.roche.com/diagnostics>) at the Mount Sinai Services Laboratory. We used serum ferritin both as a continuous variable and as a binary variable (serum ferritin <14 µg/L) to classify children as having iron deficiency, which was the cutoff used in the US National Health and Nutrition Examination Survey (NHANES).²⁸

Other Variables

Included in the analysis were covariates we *a priori* predicted might influence serum ferritin or both meat consumption and serum ferritin. These included parent-reported: age; sex; birth weight; maternal ethnicity; total breastfeeding duration (determined from the response to the question, “For how long has your child been breastfed?” – children who had never breastfed were classified as having a breastfeeding duration of 0 months and those currently breastfeeding were classified as having a breastfeeding duration equal to the child’s current age); daily cow’s milk intake (defined as daily number of 250-mL cups per day); bottle use (determined from the response to the question: “Does your child currently use a bottle?”); grain product intake (determined through parental response to the NutriSTEP® question: “My child usually eats grain products: Examples are bread, bagel, bun, cereal, pasta, rice, roti and tortillas a) More than 5 times a day; b) 4 to 5 times a day; c) 2 to 3 times a day; d) Less than 2 times a day.”); and, fruit and vegetable intake (determined from the response to the question: “Please specify your child’s diet in the past 3 days. Please check all that apply.” – those who checked *fruits* and/or *vegetables* were coded as fruit and/or vegetable intake (yes/no)). Daily cow’s milk intake was dichotomized into ≤2 cups and >2 cups per day, consistent with dietary recommendations. Also included were:

zBMI and neighbourhood household income. Trained study staff measured participants' standing height in metres (or length for children under 2 years old) and weight in kilograms with standardized instruments. BMI was calculated as kg/m^2 .²⁹ World Health Organization growth chart standards were used to determine BMI z scores.²⁹ Median after-tax neighbourhood household income was calculated based on postal code using the Statistics Canada Postal Code Conversion File and data from the 2006 Canadian Census.³⁰

Statistical Analysis

Descriptive statistics were performed for the main outcome, exposures and covariates. To assess the association between meat and meat alternatives consumption and serum ferritin level, we used a multivariable linear regression model adjusted for prespecified covariates. All covariates were specified *a priori* and included in the final model. From a previous study, serum ferritin was known to not be normally distributed.³¹ Residual plots of serum ferritin against meat consumption were generated to verify the presence of a nonlinear relationship between the main predictor and the primary outcome. To accommodate the skewed distribution, serum ferritin was log transformed and then later back-transformed to aid in the interpretation of our results. Multivariable logistic regression was used to evaluate the association between meat and meat alternatives consumption and iron deficiency, adjusting for all covariates described earlier. We used similar models to meet our secondary objective: determine the association between red meat consumption and serum ferritin level, as well as iron deficiency, among children eating meat or meat alternatives according to current Canadian guidelines.

Several biologically plausible interactions were considered, including interactions between meat consumption and each of age, sex, total breastfeeding duration, BMI z score, daily cow's milk intake, current bottle use, grain product intake and fruit and vegetable intake. A likelihood ratio test between the main effects model and the model with all plausible interaction terms yielded a joint P value of $P > 0.30$ for all models, making all hypothesized interactions unlikely. The Akaike Information Criterion (AIC) also suggested that the models without the interactions were the best fit. Multicollinearity was examined using correlation matrices and a variance inflation factor of greater than 4. We assessed our models for outliers, homoscedasticity and normality using regression diagnostics, and residual and normal quantile plots. Missing data were handled by multiple imputation using the fully conditional specification method. The maximum rate of missing data for any variable was 9%. Statistical significance was defined as $P < 0.05$; all statistical tests were two-sided. Statistical analysis was conducted using SAS statistical software version 9.3 (SAS Institute Inc., Cary, NC, USA).

RESULTS

A total of 4199 children ages 12-36 months were recruited to participate; of these, 1746 children had blood assessed for serum ferritin values (Figure 1). Previous TARGet Kids! work has found those who opt to have blood sampled are similar in demographics to those who do not.³¹ Of the 1746 children with serum ferritin values, 1187 had data on meat consumption. Of these, 55 children either had C-reactive Protein values $\geq 10\text{mg/L}$ or missing and were excluded. A further 89 children receiving iron supplementation or a daily multivitamin with iron or missing data on these variables were excluded.

Descriptive characteristics of the final study population ($n=1043$) are shown in Table 1. A total of 759 (72.8%) children ate meat or meat alternatives according to current Canadian recommendations, and 689 (66.1%) children ate red meat in the past three days. Of the 759 children meeting current Canadian recommendations for meat consumption, 535 (70.5%) children ate red meat in the past three days. Median serum ferritin was $26\text{ }\mu\text{g/L}$ (range 2-159 $\mu\text{g/L}$), and the prevalence of iron deficiency (serum ferritin $<14\text{ }\mu\text{g/L}$) was 17.0%.

In the primary analysis, using multivariable linear regression we found no association between meat or meat alternatives consumption and serum ferritin ($0.13\text{ }\mu\text{g/L}$, 95% CI: -0.05 to 0.31, $P=0.16$) (Table 2). The results of this fully adjusted analysis were not substantially different from the unadjusted analysis ($0.14\text{ }\mu\text{g/L}$, 95% CI: -0.04 to 0.31, $P=0.13$). Statistically significant covariates associated with decreased serum ferritin included longer breastfeeding duration ($-0.42\text{ }\mu\text{g/L}$ for every additional month of breastfeeding, 95% CI: -0.60 to -0.24), higher zBMI ($-1.60\text{ }\mu\text{g/L}$ for every additional unit in BMI z-score, 95% CI: -2.45 to -0.72), and daily cow's milk intake >2 cups ($-3.55\text{ }\mu\text{g/L}$, 95% CI: -5.32 to -1.64). Female sex, current bottle use,

and fruit and vegetable intake in the past 3 days were significantly associated with increased serum ferritin levels.

In univariate analyses, we found a decreased odds of iron deficiency with higher meat consumption (OR=0.97, 95% CI: 0.94 to 0.99, $P=0.04$). The proportion of children with iron deficiency among children eating meat or meat alternatives more than two times per day, two times per day, once per day, a few times per week, and not at all, was 14%, 17%, 18%, 26%, and 14%, respectively. Of the 7 children not eating any meat, while only 1 child was found to be iron deficient ($1/7=14\%$) based on the serum ferritin cut-off of $<14\text{ }\mu\text{g/L}$, 2 children had a serum ferritin of $15\text{ }\mu\text{g/L}$. After adjusting for all covariates, the association between meat or meat alternatives consumption and iron deficiency remained statistically significant (OR=0.97, 95% CI: 0.94 to 0.99, $P=0.03$) (Table 3). Statistically significant covariates associated with increased odds of iron deficiency included longer breastfeeding duration (OR=1.06, 95% CI: 1.03 to 1.09), higher zBMI (OR=1.35, 95% CI: 1.15 to 1.59), and daily cow's milk intake >2 cups (OR=1.82, 95% CI: 1.26 to 2.63).

For our secondary analysis, within the group of children who ate meat or meat alternatives according to recommendations, we found no association between red meat consumption and serum ferritin (Table 4) or with iron deficiency (Table 5). Statistically significant covariates associated with decreased serum ferritin included longer breastfeeding duration, higher zBMI, and daily cow's milk intake >2 cups. Fruit and vegetable intake in the past 3 days was significantly associated with increased serum ferritin. Longer breastfeeding duration, higher zBMI, and lower birth weight were associated with an increased odds of iron deficiency.

DISCUSSION

In this study of young, healthy Canadian children ages 12 to 36 months attending scheduled health supervision visits, 73% ate meat or meat alternatives according to Canadian recommendations (at least two times per day).¹⁹ While increased meat consumption was not associated with average serum ferritin levels, we found a very modest, but significant, 3% reduction in iron deficiency, suggesting that lower meat intake is a risk factor for iron deficiency. We found no association between red meat consumption and iron status amongst those children who ate meat or meat alternatives according to recommendations.

The odds of iron deficiency appear to decrease by 3% (OR=0.97, 95% CI: 0.94 to 0.99, $P=0.03$) with a one-unit increase in meat or meat alternatives consumption (i.e., 1 time per week). The precision of the effect estimate and hence narrow confidence interval is both due to a large sample size and treating our ordinal predictor variable as a continuous variable. The frequency of meat consumption was treated as a continuous variable assigning values to the 5 different response options to reflect weekly meat consumption and the 'true' spacing between categories (0=Not at all, 3=A few times a week, 7=Once a day, 14=2 times a day, and, 21=More than 2 times a day). P was <0.05 demonstrating a statistically significant linear trend, while the test for deviations from linearity was not significant which supports treating meat consumption as a continuous variable.

Observational studies from other developed countries, have reported a positive association between meat consumption and iron status in infancy and early childhood.⁸⁻¹¹ Differences in the measurement of meat consumption and differences in outcome variables (serum ferritin and iron deficiency) may explain why findings have been inconsistent. For example, in an analysis of data from the UK National Diet and Nutrition Survey of over 700 children aged 1.5 to 4.5 years,

children in the lowest quintile of meat consumption had the highest rates of iron deficiency (ferritin <10 µg/L).⁸ In a study of 263 healthy, 1.5- to 6-year-old children in Israel, iron deficiency was assessed according to the frequency of meat consumption in three categories: seldom, once per week, two or more times per week (4 times more likely to have iron deficiency for seldom compared with two or more times per week).¹¹ In our study, we treated the frequency of meat consumption in five categories: not at all, a few times per week, once per day, two times per day, more than two times per day, as a continuous variable and considered both serum ferritin and iron deficiency as outcome variables. Another important distinction is that only one of the previous studies controlled for a number of potential confounding variables identified in the present study¹¹ – most adjusted only for age and/or sex.

Several randomized trials have evaluated meat consumption and iron status in infants and young children.^{12–18} Two trials, from Denmark and Germany, compared a low meat and high meat intervention in the first year of life.^{12,13} One of these studies identified a difference in hemoglobin but not serum ferritin;¹² the other found no differences in hemoglobin or serum ferritin.¹³ Four studies, from Canada, the US (two studies), and a global cohort (Democratic Republic of Congo, Zambia, Guatemala, and Pakistan), compared meat and iron-fortified cereal.^{14–17} Three of these studies identified no differences in iron status;^{14–16} one large study (n=1,062) found that iron status was significantly more favorable for the cereal group.¹⁷ Finally, one trial from New Zealand compared a high-meat diet, iron-fortified milk and unmodified cow's milk in young children in the second year of life and found no differences in iron status between the three groups.¹⁸

In previous cross-sectional studies, our group identified feeding practices associated with an increased risk of iron deficiency in early childhood. We found an almost 2-fold association

between iron depletion and daytime bottle-feeding compared with cup feeding;³² an association between higher cow's milk intake and lower serum ferritin, such that every 250 mL of cow's milk consumed was associated with a 3.6% decrease in serum ferritin;³³ and, a 5% increase in odds of iron deficiency with each additional month of breastfeeding and 1.7-fold increase in the odds of iron deficiency among children who are breastfed beyond 12 months of age.³¹ Finally, a national cohort of children with severe iron deficiency anemia (hemoglobin < 80 g/L), compared with a regional cohort of iron sufficient children without anemia, consumed a larger volume of cow's milk daily, and were more likely to use a bottle during the day, and also in bed.³⁴ These findings support the AAP recommendations for increasing iron stores in young children: limiting cow's milk intake and iron supplementation for infants breastfeeding beyond 12 months of age.

An additional observation in our study was the strong negative relationship between zBMI and iron status. This suggests that overweight/obesity may be another modifiable risk factor associated with iron deficiency to be considered by primary care physicians in preventing iron deficiency in young children. We plan to further evaluate this association in a future cross-sectional analyses.

Strengths of our study include a large sample of healthy children recruited from community-based primary healthcare settings. The large sample size provided precise effect estimates and hence narrow confidence intervals. We included children attending scheduled visits for preventive care, and excluded children with laboratory evidence of elevated CRP. To measure meat consumption, we used a question from the NutriSTEP® questionnaire shown to be a valid and reliable assessment of the nutritional status of preschool-aged children.²⁶ We included other sources of iron, such as grain product intake, and the intake of fruits and vegetables which may be high in vitamin C, known to enhance non-heme iron absorption when

consumed at the same meal,³⁵ as covariates in our statistical models. Limitations of our study include the cross-sectional design from which causality cannot be determined. In addition, parent reported measurement of meat consumption may be subject to measurement error and too crude to detect associations. While they may be more time-intensive, food diaries may be a better measurement tool to assess both meat consumption and intake of fruits and vegetables. Furthermore, iron-fortified infant cereal consumption was not included as a covariate due to the high rate of missing values. However, infant cereals are intended for the 6 to 12 month age group; our age group was 12 to 36 months and after 12 months, infants should be eating table food. Further, it is possible that our measure of the frequency of meat consumption was less discriminatory (i.e., 3 of 5 response options available to parents were for ≥ 1 time per day) compared to other studies and therefore unable to detect an association with serum ferritin levels. However, less than 10% of our cohort consumed meat less than once per day. Finally, data from this population may not be generalizable to children from other urban areas or non-urban children; however, the prevalence of iron deficiency was similar to other Canadian studies of this age group.³

Conclusion

This study and other evidence suggests that excess cow's milk intake and prolonged breastfeeding are significant risk factors for iron deficiency and therefore, should be the focus of education and counseling. Higher meat or meat alternatives consumption modestly but significantly reduced the risk for iron deficiency in our cohort of healthy, young, urban Canadian children, 12 to 36 months of age. When combined with other healthy feeding practices, eating

meat according to current recommendations may be a promising additional target for the prevention of iron deficiency in early childhood.

Figure 1. Participant flow chart

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Table 1. Demographic characteristics of study participants (n=1043)

Child Characteristics	Frequency (N, %)	Median (range)
Age, months		18.3 (12.0-36.0)
Sex, Female	497 (47.7)	
Meat / meat alternatives consumption (times per week)		14 (0 - 21)*
not at all	7 (0.7)	
few times per week	78 (7.5)	
once per day	199 (19.1)	
2 times per day	522 (50.1)	
>2 times per day	237 (22.7)	
Red meat consumption in past 3 days, yes	689 (66.1)	
zBMI ^a		0.10 (-3.19 – 3.86)
Underweight ($z < -1$)	151 (14.5)	
Normal weight ($-1 \geq z \geq -1$)	672 (64.4)	
Overweight ($1 > z \geq 2$)	133 (12.8)	
Obese ($z > 2$)	50 (4.8)	
Missing	37 (3.6)	
Birth weight, kg		3.3 (0.7 – 5.2)
< 2.5	103 (9.9)	
2.5 – 4.0	767 (73.5)	
> 4.0	87 (8.3)	
Missing	86 (8.3)	
Maternal Ethnicity		
Caucasian	684 (65.6)	
Asian	192 (18.4)	
Other ^a	81 (7.8)	
Missing	86 (8.3)	
Median after-tax neighbourhood household income, Can \$ ^a		
0–29,999	55 (5.3)	
30,000–79,999	765 (73.4)	
≥ 80,000	125 (12.0)	
Missing	98 (9.4)	
Total breastfeeding duration, months		12.0 (0-30.0)
0 – 6 months	157 (15.1)	
6 – 12 months	431 (41.3)	
12 – 24 months	369 (35.4)	
≥ 24 months	20 (1.9)	
Missing	66 (6.3)	
Daily cow's milk intake, cups		2.0 (0-5.0)
Cow's milk intake >2 cups/day, yes	309 (29.6)	
Missing	27 (2.6)	
Current bottle use, yes	496 (47.6)	
Missing	59 (5.7)	

Grain product intake		
less than 2 times a day	79 (7.6)	
2 to 3 times a day	582 (55.8)	
4 to 5 times a day	320 (30.7)	
more than 5 times a day	62 (5.9)	
Fruit / vegetable intake in past 3 days, yes	5863 (56.2)	
Serum ferritin ($\mu\text{g/L}$)		26 (2 – 159)
Iron deficiency, yes	177 (17.0)	
(serum ferritin $<14 \mu\text{g/L}$)		
Hemoglobin (g/L)		120 (78 - 151)
Missing	43 (4.1)	
Iron deficiency anemia, yes		
(serum ferritin $<14 \mu\text{g/L}$ and		
hemoglobin $\leq 110 \text{ g/L}$)	41 (3.9)	
Missing	43 (4.1)	

^aBMI = body mass index; Other includes: African, Caribbean, Latin American, North American Aboriginal; Can \$ = Canadian dollar

*759 parents (72.8%) reported that their child usually eats meat, fish, poultry or alternatives ≥ 2 times per day, which is according to recommendations

Table 2. Adjusted linear regression model for the association between meat consumption and median serum ferritin ($\mu\text{g/L}$)

Predictor	β (log) (95% CI)		Percent Change in Serum Ferritin	Change in Median Serum Ferritin $\mu\text{g/L}$ (95% CI) ^b		P Value
Meat / meat alternatives consumption	0.005	(-0.002, 0.012)	0.51%	0.13	(-0.05, 0.31)	0.16
Age, months	- 0.0009	(-0.008, 0.006)	- 0.09%	- 0.02	(-0.20, 0.15)	0.79
Sex, Female	0.084	(0.008, 0.160)	8.78%	2.20	(0.20, 4.35)	0.03 ^a
zBMI, unit	- 0.066	(-0.103, -0.029)	- 6.40%	- 1.60	(-2.45, -0.72)	0.0004 ^a
Birth weight, kg	0.012	(-0.053, 0.077)	1.20%	0.30	(-1.29, 2.00)	0.72
Maternal ethnicity						
Caucasian	--	--	--	--	--	--
Asian	0.019	(-0.086, 0.124)	1.94%	0.49	(-2.05, 3.31)	0.72
Other	- 0.005	(-0.156, 0.146)	- 0.49%	- 0.12	(-3.61, 3.93)	0.95
Median neighbourhood household income						
\$0-29,999	0.046	(-0.151, 0.244)	4.72%	1.18	(-3.51, 6.90)	0.65
\$30,000-79,999	0.044	(-0.072, 0.160)	4.52%	1.13	(-1.73, 4.34)	0.45
$\geq$ \$80,000	--	--	--	--	--	--
Breastfeeding duration, months	- 0.017	(-0.024, -0.010)	- 1.68%	- 0.42	(-0.60, -0.24)	<0.0001 ^a
Daily cow's milk intake >2 cups/day, yes	- 0.153	(-0.239, -0.068)	- 14.22%	- 3.55	(-5.32, -1.64)	0.0005 ^a
Current bottle use, yes	0.096	(0.010, 0.183)	10.13%	2.53	(0.24, 5.03)	0.03 ^a
Grain product intake						
less than 2 times a day	0.135	(-0.079, 0.350)	14.51%	3.63	(-1.89, 10.46)	0.21
2 to 3 times a day	0.005	(-0.161, 0.172)	0.53%	0.13	(-3.72, 4.69)	0.95
4 to 5 times a day	0.052	(-0.119, 0.223)	5.39%	1.35	(-2.80, 6.26)	0.55
more than 5 times a day	--	--	--	--	--	--
Fruit / vegetable intake in past 3 days, yes	0.094	(0.013, 0.176)	9.91%	2.48	(0.33, 4.81)	0.02 ^a

Note: Adjusted beta estimates are reported to 3 decimal places for statistical precision. Negative values indicate a decrease in median serum ferritin, positive values indicate an increase in median serum ferritin. Adjusted $R^2 = .0653$. ^aStatistically significant effects.

Table 3. Adjusted logistic regression model for association between meat consumption and iron deficiency (serum ferritin <14 µg/L)

Predictor	β (95% CI)		OR (95% CI)	P
Meat/meat alternatives consumption	- 0.034	(-0.065, -0.003)	0.97 (0.94, 0.99)	0.03 ^a
Age, months	- 0.027	(-0.059, 0.005)	0.97 (0.94, 1.01)	0.10
Sex, Female	- 0.110	(-0.449, 0.229)	0.90 (0.64, 1.26)	0.52
zBMI, unit	0.302	(0.138, 0.466)	1.35 (1.15, 1.59)	0.0003 ^a
Birth weight, kg	- 0.229	(-0.512, 0.055)	0.80 (0.60, 1.06)	0.11
Maternal ethnicity				
Caucasian	--	--	1.00	--
Asian	- 0.052	(-0.521, 0.416)	0.95 (0.59, 1.52)	0.83
Other	0.018	(-0.636, 0.672)	1.02 (0.53, 1.96)	0.96
Median neighbourhood household income				
\$0-29,999	- 0.006	(-0.837, 0.825)	0.99 (0.43, 2.28)	0.99
\$30,000-79,999	- 0.281	(-0.777, 0.215)	0.76 (0.46, 1.24)	0.27
≥\$80,000	--	--	1.00	--
Breastfeeding duration, months	0.058	(0.026, 0.090)	1.06 (1.03, 1.09)	0.0004 ^a
Daily cow's milk intake >2 cups/day, yes	0.599	(0.231, 0.967)	1.82 (1.26, 2.63)	0.001 ^a
Current bottle use, yes	- 0.344	(-0.726, 0.038)	0.71 (0.48, 1.04)	0.08
Grain product intake				
less than 2 times a day	- 0.946	(-1.984, 0.093)	0.39 (0.14, 1.10)	0.07
2 to 3 times a day	- 0.115	(-0.837, 0.607)	0.89 (0.43, 1.84)	0.76
4 to 5 times a day	- 0.431	(-1.185, 0.322)	0.65 (0.31, 1.38)	0.26
more than 5 times a day	--	--	1.00	--
Fruit and/or vegetable intake in past 3 days, yes	- 0.222	(-0.582, 0.138)	0.80 (0.56, 1.15)	0.23
Test	χ^2		df	P
Overall model evaluation - Likelihood ratio test	53.62		16	<0.0001
Goodness-of-fit test - Hosmer & Lemeshow	8.56		8	0.38

Note: Adjusted beta estimates are reported to 3 decimal places for statistical precision. Negative values indicate a decrease in iron deficiency, positive values indicate an increase in iron deficiency. Adjusted $R^2 = .0838$. ^aStatistically significant effects.

Table 4. Adjusted linear regression model for the association between red meat consumption and median serum ferritin ($\mu\text{g/L}$) among children who eat meat or meat alternatives according to recommendations

Predictor	β (log) (95% CI)	Percent Change in Serum Ferritin	Change in Median Serum Ferritin $\mu\text{g/L}$ (95% CI) ^b	P Value
Red meat consumption in past 3 days, yes	- 0.018 (-0.114, 0.078)	- 1.78%	- 0.45 (-2.70, 2.03)	0.71
Age, months	- 0.003 (-0.011, 0.006)	- 0.26%	- 0.07 (-0.27, 0.14)	0.54
Sex, Female	0.086 (-0.004, 0.175)	8.93%	2.23 (-0.09, 4.77)	0.06
zBMI, unit	- 0.056 (-0.100, -0.011)	- 5.42%	- 1.35 (-2.38, -0.28)	0.01 ^a
Birth weight, kg	0.025 (-0.051, 0.102)	2.57%	0.64 (-1.25, 2.69)	0.52
Maternal ethnicity				
Caucasian	-- --	--	-- --	--
Asian	0.042 (-0.075, 0.160)	4.33%	1.08 (-1.81, 4.33)	0.48
Other	- 0.095 (-0.274, 0.084)	- 9.05%	- 2.26 (-5.99, 2.20)	0.30
Median neighbourhood household income				
\$0-29,999	0.064 (-0.167, 0.294)	6.56%	1.64 (-3.84, 8.54)	0.59
\$30,000-79,999	0.048 (-0.081, 0.176)	4.87%	1.22 (-1.95, 4.82)	0.47
$\geq$ \$80,000	-- --	--	-- --	--
Breastfeeding duration, months	- 0.017 (-0.026, -0.008)	- 1.70%	- 0.42 (-0.64, -0.21)	0.0001 ^a
Daily cow's milk intake >2 cups/day, yes	- 0.123 (-0.223, -0.022)	- 11.56%	- 2.89 (-5.00, -0.56)	0.02 ^a
Current bottle use, yes	0.073 (-0.027, 0.173)	7.58%	1.89 (-0.67, 4.73)	0.15
Grain product intake				
less than 2 times a day	0.060 (-0.210, 0.330)	6.16%	1.54 (-4.74, 9.77)	0.66
2 to 3 times a day	0.026 (-0.171, 0.223)	2.65%	0.66 (-3.93, 6.25)	0.79
4 to 5 times a day	0.065 (-0.135, 0.264)	6.66%	1.67 (-3.17, 7.57)	0.53
more than 5 times a day	-- --	--	-- --	--
Fruit / vegetable intake in past 3 days, yes	0.109 (0.014, 0.204)	11.55%	2.89 (0.36, 5.67)	0.02 ^a

Note: Adjusted beta estimates are reported to 3 decimal places for statistical precision. Negative values indicate a decrease in median serum ferritin, positive values indicate an increase in median serum ferritin. Adjusted $R^2 = .0595$. ^aStatistically significant effects.

Table 5. Adjusted logistic regression model for association between red meat consumption and iron deficiency (<14 µg/L) among children who eat meat or meat alternatives according to recommendations

Predictor	β (95% CI)		OR (95% CI)	P
Red meat consumption in past 3 days, yes	0.228	(-0.235, 0.691)	1.26 (0.79, 1.99)	0.33
Age, months	- 0.031	(-0.071, 0.009)	0.97 (0.93, 1.01)	0.13
Sex, Female	- 0.078	(-0.491, 0.334)	0.92 (0.61, 1.40)	0.71
zBMI, unit	0.339	(0.131, 0.546)	1.40 (1.14, 1.73)	0.001 ^a
Birth weight, kg	- 0.397	(-0.740, -0.054)	0.67 (0.48, 0.95)	0.02 ^a
Maternal ethnicity				
Caucasian	--	--	1.00	--
Asian	- 0.252	(-0.812, 0.308)	0.78 (0.44, 1.36)	0.38
Other	0.305	(-0.422, 1.031)	1.36 (0.66, 2.80)	0.41
Median neighbourhood household income				
\$0-29,999	- 0.504	(-1.568, 0.561)	0.60 (0.21, 1.75)	0.35
\$30,000-79,999	- 0.359	(-0.920, 0.201)	0.70 (0.40, 1.22)	0.21
≥\$80,000	--	--	1.00	--
Breastfeeding duration, months	0.070	(0.030, 0.110)	1.07 (1.03, 1.12)	0.0007 ^a
Daily cow's milk intake >2 cups/day, yes	0.401	(-0.048, 0.850)	1.49 (0.95, 2.34)	0.08
Current bottle use, yes	- 0.216	(-0.669, 0.236)	0.81 (0.51, 1.27)	0.35
Grain product intake				
less than 2 times a day	- 1.219	(-2.720, 0.282)	0.30 (0.07, 1.33)	0.11
2 to 3 times a day	- 0.154	(-1.049, 0.741)	0.86 (0.35, 2.10)	0.74
4 to 5 times a day	- 0.468	(-1.385, 0.448)	0.63 (0.25, 1.57)	0.32
more than 5 times a day	--	--	1.00	--
Fruit and/or vegetable intake in past 3 days, yes	- 0.325	(-0.760, 0.110)	0.72 (0.47, 1.12)	0.14
Test	χ^2		df	P
Overall model evaluation - Likelihood ratio test	39.38		16	0.001
Goodness-of-fit test - Hosmer & Lemeshow	5.96		8	0.65

Note: Adjusted beta estimates are reported to 3 decimal places for statistical precision. Negative values indicate a decrease in iron deficiency, positive values indicate an increase in iron deficiency. Adjusted $R^2 = .0868$. ^aStatistically significant effects.