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Maternal ethnicity and iron status in early childhood in Toronto, Canada: a cross-sectional study

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ABSTRACT

Objectives This study aimed to evaluate the association between maternal ethnicity and iron deficiency (ID) in early childhood, and to evaluate whether infant feeding practices linked to ID differ between maternal ethnic groups.

Methods This was a cross-sectional study of healthy children 1–3 years of age. Adjusted multivariable logistic regression analyses were used to evaluate the association between maternal ethnicity and ID (serum ferritin <12 µg/L) and the association between maternal ethnicity and five infant feeding practices (breastfeeding duration; bottle use beyond 15 months; current formula use; daily cow's milk intake >2 cups; meat consumption).

Results Of 1851 children included, 12.2% had ID. Compared with the European referent group, we found higher odds of ID among children of South Asian and West Asian/North African maternal ethnicities, and lower odds of ID among children of East Asian maternal ethnicity. Statistically significant covariates associated with higher odds of ID included longer breastfeeding duration and daily cow's milk intake >2 cups. Current infant formula use was associated with lower odds of ID. Children of South Asian maternal ethnicity had higher odds of bottle use beyond 15 months of age and lower odds of meat consumption.

Conclusions We found increased odds of ID among children of South Asian and West Asian/Northern African maternal ethnicities. We found a higher odds of feeding practices linked to ID in children of South Asian maternal ethnicity, but not in children of West Asian/North African maternal ethnicity. Culturally tailored approaches to providing guidance to parents on healthy infant feeding practices may be important to prevent ID in early childhood.

Trial registration number NCT01869530.

What is known about the subject?

- ► Iron deficiency (ID) may negatively impact child development and has many risk factors, including specific infant feeding practices.
- ► However, the differences in prevalence of ID and feeding practices between maternal ethnic groups are unknown.

What this study adds?

- ► Children of South Asian and West Asian/Northern African maternal ethnicities had higher odds of iron deficiency (ID).
- ► Feeding practices linked to ID were found in children of South Asian maternal ethnicity, but not in children of West Asian/North African maternal ethnicity.
- ► Culturally tailored approaches to providing guidance to parents on healthy infant feeding practices may be important to prevent ID in young children.

INTRODUCTION

Iron deficiency (ID) is the most common nutritional deficiency worldwide.[1] Early childhood is a sensitive period for brain development and the age of peak prevalence for ID.[2] ID and iron deficiency anaemia (IDA) have been associated with immediate and long-term neurodevelopmental impairment.[3 4]

For infants 1–3 years of age, several feeding practices have been linked to iron status including duration of breastfeeding, bottle use, volume of cow's milk consumed, consumption of meat and meat alternatives, and use of formula.[5–9] Few studies have explored the relationship between maternal ethnicity, iron status and feeding practices in young children in developed countries such as Canada, the UK and the USA.[10–16] Furthermore, these studies were conducted 15–30 years ago.

Toronto is Canada's largest city and the most recent national census reported that 51.5% of the city's population were visible minorities, of which 75% were South Asian, Chinese, Black or Filipino.[17] Toronto's ethnic diversity provided an opportunity to undertake a contemporary examination of the relationship between maternal ethnicity, iron status and feeding practices in young children.

The primary objective of our study was to evaluate the association between maternal ethnicity and iron status in early childhood. A secondary objective was to evaluate whether infant feeding practices known to be associated with ID differ between maternal ethnic groups.

METHODS

Study design and population

We conducted a cross-sectional study of healthy children 1–3 years of age, recruited during scheduled health supervision visits at TARGet Kids! primary care practices between September 2008 and July 2017. TARGet Kids! is a primary care research network and ongoing open longitudinal cohort study recruiting healthy young children and following them into adolescence. The aim of the cohort is to link early life exposures to health problems, including micronutrient deficiencies (www.targetkids.ca).[18] Trained research assistants collect sociodemographic and nutritional data using a standardised, parent-completed questionnaire (based on the Canadian Community Health Survey), anthropometric measurements and blood samples (haemoglobin, serum ferritin, C reactive protein (CRP)).[18 19] In Canada, delayed clamping of the umbilical cord is recommended; as there are no recommendations regarding universal or targeted screening for ID, blood samples were collected for research purposes.

TARGet Kids! exclusion are: <32 weeks gestational age; health conditions affecting growth; chronic conditions (other than asthma); severe developmental delay; unscheduled visit because of acute illness; parents unable to communicate in English.[18] Children were included if they were 12–38 months of age (to capture children attending health supervision visits scheduled at: 12 months, 15 months, 18 months, 2 years, 3 years) and had complete data on exposure and outcome including maternal ethnicity, serum ferritin and CRP. Children with serum ferritin >200 µg/L were excluded, as this is beyond the upper limit of the reference interval.[19 20] Children with CRP ≥10 mg/L were excluded since this may indicate acute systemic inflammation.[2] Children taking iron supplementation were excluded.

Consent was obtained from parents of children participating in TARGet Kids!.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research. Patients were not invited to comment on the study design and were not consulted to interpret the results. They were not invited to contribute to the writing or editing of this document.

Variables

The primary exposure was maternal ethnicity, determined by responses on the parent-completed questionnaire. Following the Canadian census, our questionnaire asks about maternal ethnicity based on geographical regions defined by the United Nations.[21] The nine maternal ethnic groups can be found in table 1. The closed-ended question shows good agreement and accuracy compared with an open-ended question.[22] Mixed maternal ethnicity was used when parents responded with two or more ethnic groups.

The primary outcome measure was iron status, measured through binary variables indicating the presence of ID (serum ferritin <12 µg/L) and IDA (serum

Table 1 Subclassification of maternal ethnicity in TARGet Kids!

Ethnicity	Response options on TARGet Kids! questionnaire
European	Eastern European (eg, Polish, Russian, Croatian) Western European (eg, English, French, Portuguese) Australian or New Zealander
East Asian	East Asian (Chinese) East Asian (Korean) East Asian (Japanese)
Southeast Asian	Southeast Asian (eg, Vietnamese, Malaysian, Filipino) Oceania (eg, Samoan, Fijian)
South Asian	South Asian (eg, East Indian, Pakistani, Sri Lankan) Indian-Caribbean
West Asian/North African	West Asian (eg, Iranian, Afghan, Palestinian) North African (eg, Moroccan, Algerian, Egyptian, Sudanese)
African and Caribbean	East African (eg, Ethiopian, Kenyan, Somali) Middle African (eg, Cameroonian, Chadian, Congolese) Southern African (eg, Botswana, South African) Western African (eg, Ghanaian, Nigerian, Guinean) Caribbean Region (eg, Jamaican, Guyana, Trinidadian/Tobagonian)
Latin American	Latin American (eg, Argentinean, Costa Rican, Mexican)
Indigenous	North American Indigenous (Inuit, Métis, First Nations)
Mixed	Two or more of the listed ethnic groups above

ferritin <12 µg/L and haemoglobin ≤110 g/L), as suggested by the WHO and the American Academy of Paediatrics for this age group.[2 23]

Demographic covariates that might influence iron status were included in the analysis: child sex, child age, birth weight, maternal education and family income. In a previous analysis, we did not identify an association between family immigration status and iron status, and therefore did not include this variable as a covariate.[24] Body mass index (BMI) was found to be associated with iron status and was therefore included in the analysis.[25] BMI was calculated as kg/m^2, and WHO growth chart standards were used to determine BMI z score (zBMI).

Five infant feeding practices were *a priori* identified as covariates,[5–9] and included as secondary outcomes: breastfeeding duration; bottle use beyond 15 months of age; current infant formula use; daily cow's milk intake greater than two cups (500 mL); meat consumption (including red meat, poultry, fish, shellfish and eggs) in the last 3 days. Prolonged bottle use is associated with ID.[5 13] Research suggests that a child's lack of self-regulation of milk intake with a bottle can lead to excessive daily consumption of cow's milk, which in turn can lead to ID due to the low absorbable iron content in cow's milk.[5 8] Children who were never breastfed were classified as having a breastfeeding duration of 0 months, and children currently breastfeeding were classified as having a breastfeeding duration equal to their current age. Maternal recall has been found to be a valid and reliable estimate of breastfeeding duration.[26]

Statistical analyses

Descriptive statistics were performed for the main outcome, exposures and covariates. The prevalence of ID and IDA were determined for children in each of the nine maternal ethnic groups. For our primary objective, we used two multivariable logistic regression models to evaluate the association between maternal ethnicity and ID and IDA. Because of the lack of heterogeneity found across the cohort for meat consumption, this variable was not included in this set of regression models. For our secondary objective, we used multivariable logistic regression models for the association between maternal ethnicity and each of the five infant feeding practices. The European maternal ethnic category was used as the referent group. All models were adjusted for all prespecified covariates regardless of statistical significance.[27] Restricted cubic spline analysis was used to test for a non-linear relationship between age and serum ferritin and then confirmed by loess curves, selecting three knot points to correspond to the age at scheduled visits (15, 18 and 24 months).[28] Multiple imputation using the fully conditional specification method was used to handle missing data. All covariates had <15% missing data. Statistical significance was defined as p<0.05, and all statistical tests were two-sided. Statistical analysis was conducted by SAS V.9.4 statistical software (SAS Institute).

Table 2 Participant recruitment and selection of patients for inclusion (n=1851)

Characteristic	No.
Consent obtained from parents of healthy children between ages 12 and 38 months enrolled in the TARGet Kids! cohort	4995
Exclusion criteria	
1. No maternal ethnicity data	481
2. No serum ferritin data	2413
3. Serum ferritin value>200 µg/L	1
4. CRP≥10 mg/L or missing	61
5. Receiving iron supplementation	44
6. Receiving multivitamins with iron	65
7. Receiving both iron supplementation and multivitamins with iron	1
8. Missing iron supplementation data	78
Final cohort	1851

CRP, C reactive protein.

RESULTS

We obtained a final cohort of 1851 children (table 2). Patient-level characteristics, laboratory characteristics and infant feeding practices are shown in table 3. The prevalence of ID was 12.2%.

Compared with the European referent group, we found higher odds of ID among children of South Asian (OR 1.68, 95% CI 1.04 to 2.70, p=0.03) and West Asian/North African (OR 2.40, 95% CI 1.03 to 5.60, p=0.04) maternal ethnicities, and lower odds of ID among children of East Asian maternal ethnicity (OR 0.36, 95% CI 0.14 to 0.92, p=0.03) (table 4). Among the infant feeding practices, statistically significant covariates associated with higher odds of ID included longer breastfeeding duration (OR 1.05, 95% CI 1.03 to 1.08, p=0.0001) and daily cow's milk intake >2 cups (OR 1.61, 95% CI 1.17 to 2.21, p=0.004). Current infant formula use was associated with lower odds of ID (OR 0.10, 95% CI 0.04 to 0.30, p<0.0001).

Among the 1567 children with available haemoglobin data, the prevalence of IDA was 4.2%. Using multivariable logistic regression, we found no association between maternal ethnicity and IDA (table 4). In terms of infant feeding practices, statistically significant covariates associated with higher odds of IDA included longer breastfeeding duration (OR 1.06, 95% CI 1.01 to 1.11, p=0.02); current infant formula use was associated with lower odds of IDA (OR 0.14, 95% CI 0.03 to 0.62, p=0.009).

When investigating infant feeding practices across ethnic groups using the European maternal ethnic group as the referent group (table 5), children of South Asian maternal ethnicity had higher odds of bottle use beyond 15 months of age (OR 2.37, 95% CI 1.48 to 3.81, p=0.0003) and lower odds of meat consumption in the last 3 days (OR 0.32, 95% CI 0.17 to 0.60, p=0.0004). Additionally, children of Southeast Asian (OR 2.85, 95% CI 1.24

Table 3 Baseline characteristics of study cohort by exposure variable: maternal ethnicity

Characteristic	Total	European*	East Asian	Southeast Asian	South Asian	West Asian / North African	African and Caribbean	Latin American	Indigenous	Mixed
N	**1851**	**1214**	**105**	**65**	**169**	**43**	**79**	**57**	**6**	**113**
Patient-level characteristics										
Female sex	908 (49.1)	591 (48.7)	58 (55.2)	39 (60.0)	71 (42.0)	17 (39.5)	42 (53.2)	31 (54.4)	2 (33.3)	57 (50.4)
Child's age, months										
12–15	597 (32.3)	400 (33.0)	26 (24.8)	18 (27.7)	46 (27.2)	20 (46.5)	26 (32.9)	20 (35.1)	4 (66.7)	37 (32.7)
15–18	298 (16.1)	196 (16.1)	17 (16.2)	8 (12.3)	19 (11.2)	7 (16.3)	19 (24.1)	6 (10.5)	0 (0)	26 (23.0)
18–24	410 (22.2)	263 (21.7)	26 (24.8)	18 (27.7)	45 (26.6)	8 (18.6)	16 (20.3)	14 (24.6)	1 (16.7)	19 (16.8)
24–38	546 (29.5)	355 (29.2)	36 (34.3)	21 (32.3)	59 (34.9)	8 (18.6)	18 (22.8)	17 (29.8)	1 (16.7)	31 (27.4)
Gestational age, weeks										
32–36	211 (11.4)	123 (10.1)	14 (13.3)	4 (6.2)	33 (19.5)	5 (11.6)	11 (13.9)	6 (10.5)	1 (16.7)	14 (12.4)
≥37	1392 (75.2)	932 (76.8)	76 (72.4)	41 (63.1)	117 (69.2)	25 (58.2)	63 (79.8)	46 (80.7)	5 (83.3)	87 (77.0)
Missing	248 (13.4)	159 (13.1)	15 (14.3)	20 (30.8)	19 (11.2)	13 (30.2)	5 (6.3)	5 (8.8)	0 (0)	12 (10.6)
Birth weight, kg										
<2.5	195 (10.5)	109 (9.0)	12 (11.4)	5 (7.7)	26 (15.4)	5 (11.6)	18 (22.8)	9 (15.8)	1 (16.7)	10 (8.9)
≥2.5	1525 (82.4)	1028 (84.7)	82 (78.1)	53 (81.5)	127 (75.2)	34 (79.1)	59 (74.7)	41 (71.9)	5 (83.3)	96 (84.9)
Missing	131 (7.1)	77 (6.3)	11 (10.5)	7 (10.8)	16 (9.5)	4 (9.3)	2 (2.5)	7 (12.3)	0 (0)	7 (6.2)
zBMI										
Underweight (z<−2)	48 (2.6)	24 (2.0)	3 (2.9)	2 (3.0)	9 (5.3)	0 (0)	2 (2.5)	2 (3.5)	0 (0)	6 (5.3)
Normal weight (−2≤z≤1)	1393 (75.3)	908 (74.8)	80 (76.2)	54 (83.1)	130 (76.9)	35 (81.4)	57 (72.2)	40 (70.2)	6 (100)	83 (73.5)
At-risk-of-overweight (1<z ≤ 2)	277 (15.0)	197 (16.2)	12 (11.4)	5 (7.7)	16 (9.5)	7 (16.3)	15 (19.0)	10 (17.5)	0 (0)	15 (13.3)
Overweight (2<z≤ 3)	64 (3.5)	43 (3.5)	5 (4.8)	2 (3.1)	4 (2.4)	0 (0)	3 (3.8)	2 (3.5)	0 (0)	5 (4.4)
Obese (z>3)	11 (0.6)	6 (0.5)	1 (1.0)	0 (0)	2 (1.2)	0 (0)	1 (1.3)	1 (1.8)	0 (0)	0 (0)
Missing	58 (3.1)	36 (3.0)	4 (3.8)	2 (3.1)	8 (4.7)	1 (2.3)	1 (1.3)	2 (3.5)	0 (0)	4 (3.5)
Maternal education										
Post-Secondary	1665 (90.0)	1117 (92.0)	102 (97.1)	61 (93.9)	141 (83.4)	33 (76.7)	57 (72.2)	48 (84.2)	6 (100)	100 (88.5)
No post-Secondary	149 (8.0)	76 (6.3)	3 (2.9)	4 (6.1)	20 (11.8)	8 (18.6)	20 (25.3)	7 (12.3)	0 (0)	11 (9.7)
Missing	37 (2.0)	21 (1.7)	0 (0)	0 (0)	8 (4.7)	2 (4.7)	2 (2.5)	2 (3.5)	0 (0)	2 (1.8)
Family income (CAN $)										
< $30 000	106 (5.7)	24 (2.0)	2 (1.9)	7 (10.8)	29 (17.2)	6 (14.0)	20 (25.3)	10 (17.5)	1 (16.7)	7 (6.2)
$30 000 to $79 999	275 (14.9)	120 (9.9)	14 (13.3)	17 (26.2)	52 (30.8)	10 (23.3)	20 (25.3)	17 (29.8)	1 (16.7)	24 (21.2)
$80 000+	1187 (64.1)	880 (72.5)	74 (70.5)	27 (41.5)	66 (39.1)	20 (46.5)	26 (32.9)	24 (42.1)	3 (50.0)	67 (59.3)
Missing	283 (15.3)	190 (15.7)	15 (14.3)	14 (21.5)	22 (13.0)	7 (16.3)	13 (16.5)	6 (10.5)	1 (16.7)	15 (13.3)
Family immigration status										
Non-immigrant (Cdn born)	943 (50.9)	809 (66.6)	24 (22.9)	10 (15.4)	23 (13.6)	10 (23.3)	17 (21.5)	6 (10.5)	5 (83.3)	39 (34.5)
Immigrant, industrialised	306 (16.5)	239 (19.7)	29 (27.6)	1 (1.5)	8 (4.7)	6 (14.0)	1 (1.3)	1 (1.8)	0 (0)	21 (18.6)
Immigrant, non-industrialised	551 (29.8)	133 (11.0)	49 (46.7)	53 (81.5)	133 (78.7)	23 (53.5)	61 (77.2)	49 (86.0)	1 (16.7)	49 (43.4)
Missing	51 (2.8)	33 (2.7)	3 (2.9)	1 (1.5)	5 (3.0)	4 (9.3)	0 (0)	1 (1.8)	0 (0)	4 (3.5)

Continued

Table 3 Continued

Characteristic	Total	European*	East Asian	Southeast Asian	South Asian	West Asian / North African	African and Caribbean	Latin American	Indigenous	Mixed
N	**1851**	**1214**	**105**	**65**	**169**	**43**	**79**	**57**	**6**	**113**
Laboratory characteristics										
CRP level										
≤1.0 mg/L	1532 (82.8)	990 (81.6)	89 (84.8)	55 (84.6)	145 (85.8)	36 (79.1)	62 (78.5)	51 (89.5)	5 (83.3)	99 (87.6)
>1.0 to <10.0 mg/L	311 (16.8)	218 (18.0)	16 (15.2)	10 (15.4)	23 (13.6)	7 (16.3)	17 (21.5)	6 (10.5)	1 (16.70	13 (11.5)
Missing	8 (0.4)	6 (0.5)	0 (0)	0 (0)	1 (0.6)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.9)
Serum ferritin (µg/L)	23 (16 to 35)	23 (16 to 34)	28 (19 to 41)	31 (19 to 46)	22 (14 to 33)	22 (13 to 39)	27 (17 to 45)	22 (17 to 30)	18 (12 to 25)	22 (14 to 36)
Haemoglobin (g/L)	119 (114 to 124)	119 (114 to 123)	122 (116 to 126)	119 (113 to 126)	119 (113 to 126)	117 (116 to 124)	117 (110 to 123)	120 (117 to 125)	123 (110 to 124)	121 (114 to 127)
Missing	284 (15.3)	198 (16.3)	19 (18.1)	12 (18.5)	13 (7.7)	6 (14.0)	10 (12.7)	13 (22.8)	0 (0)	13 (11.5)
Iron deficiency, yes	226 (12.2)	139 (11.5)	5 (4.8)	5 (7.7)	34 (20.1)	9 (20.9)	7 (8.9)	7 (12.3)	1 (16.7)	19 (16.8)
Iron deficiency anaemia, yes	66 (3.8)	39 (3.2)	1 (1.0)	1 (1.5)	8 (4.7)	1 (2.3)	5 (6.3)	2 (3.5)	1 (16.7)	8 (7.1)
Missing	284 (15.3)	198 (16.3)	19 (18.1)	12 (18.5)	13 (7.7)	6 (13.9)	10 (12.7)	13 (22.8)	0 (0)	13 (11.5)
Infant feeding practices										
Breastfeeding duration										
≤12 months	960 (51.9)	634 (52.2)	56 (53.3)	39 (60.0)	90 (53.3)	23 (52.5)	43 (54.4)	26 (45.6)	4 (66.6)	45 (39.8)
>12 months	789 (42.6)	511 (42.1)	47 (44.8)	21 (32.3)	71 (42.0)	19 (44.2)	30 (38.0)	27 (47.4)	1 (16.7)	62 (54.9)
Missing	102 (5.5)	69 (5.7)	2 (1.9)	5 (7.7)	8 (4.7)	1 (2.3)	6 (7.6)	4 (7.0)	1 (16.7)	6 (5.3)
Cow's milk consumption										
≤2 cups (500 mL)	1306 (70.6)	874 (72.0)	79 (75.2)	39 (60.0)	106 (62.7)	30 (69.8)	49 (62.0)	38 (66.7)	4 (66.7)	87 (77.0)
>2 cups (500 mL)	503 (27.2)	316 (26.0)	24 (22.9)	23 (35.4)	59 (34.9)	11 (25.6)	28 (35.4)	19 (33.3)	2 (33.3)	21 (18.6)
Missing	42 (2.2)	24 (2.0)	2 (1.9)	3 (4.6)	4 (2.4)	2 (4.7)	2 (2.5)	0 (0.0)	0 (0.0)	5 (4.4)
Bottle use duration										
≤15 months	1127 (60.9)	772 (63.6)	63 (60.0)	31 (47.7)	80 (47.3)	28 (65.1)	43 (54.4)	32 (56.1)	4 (66.7)	74 (65.5)
>15 months	538 (29.1)	317 (26.1)	26 (24.8)	25 (38.5)	75 (44.4)	13 (30.2)	29 (36.7)	22 (38.6)	2 (33.3)	29 (25.7)
Missing	186 (10.0)	125 (10.3)	16 (15.2)	9 (13.9)	14 (8.2)	2 (4.7)	7 (8.9)	3 (5.3)	0 (0)	10 (8.9)
Meat consumption										
Yes	1777 (96.0)	1175 (96.8)	105 (100.0)	61 (93.9)	150 (88.8)	42 (97.7)	74 (93.7)	56 (98.3)	6 (100.0)	108 (95.6)
No	69 (3.7)	36 (3.0)	0 (0.0)	3 (4.6)	18 (10.7)	1 (2.3)	5 (6.3)	1 (1.8)	0 (0.0)	5 (4.4)
Missing	5 (0.3)	3 (0.2)	0 (0.0)	1 (1.5)	1 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Infant formula use										
Yes	261 (14.1)	157 (12.9)	12 (11.4)	13 (20.0)	20 (11.8)	12 (27.9)	20 (25.3)	7 (12.3)	2 (33.3)	18 (15.9)
No	1368 (73.9)	928 (76.4)	80 (76.2)	40 (61.5)	123 (72.8)	24 (55.8)	49 (62.0)	42 (73.7)	4 (66.7)	78 (69.0)
Missing	222 (12.0)	129 (10.6)	13 (12.4)	12 (18.5)	26 (15.4)	7 (16.3)	10 (12.7)	8 (14.0)	0 (0.0)	17 (15.0)

Data regarding baseline characteristics are presented as n (%) or median (IQR).
CRP, C reactive protein; zBMI, body mass index z score.

Table 4 Multivariable logistic regression model for the association between maternal ethnicity and iron deficiency and iron deficiency anaemia

	Iron deficiency (ID)			Iron deficiency Anaemia (IDA)		
Variable	**ß (95% CI)**	**OR (95% CI)**	**P value**	**ß (95% CI)**	**OR (95% CI)**	**P value**
Maternal ethnicity						
European		Referent			Referent	
East Asian	−1.013 (−1.947 to −0.079)	0.36 (0.14 to 0.92)	0.03*	−1.025 (−3.039 to 0.989)	0.36 (0.05 to 2.69)	0.32
Southeast Asian	−0.355 (−1.337 to 0.627)	0.70 (0.26 to 1.87)	0.48	−0.658 (−2.708 to 1.392)	0.52 (0.07 to 4.02)	0.53
South Asian	0.518 (0.043 to 0.993)	1.68 (1.04 to 2.70)	0.03*	0.190 (−0.661 to 1.040)	1.21 (0.52 to 2.83)	0.66
West Asian/North African	0.876 (0.031 to 1.722)	2.40 (1.03 to 5.60)	0.04*	−0.707 (−2.817 to 1.404)	0.49 (0.06 to 4.07)	0.51
African and Caribbean	−0.515 (−1.397 to 0.367)	0.60 (0.25 to 1.44)	0.25	0.246 (−0.875 to 1.367)	1.28 (0.42 to 3.92)	0.67
Latin American	−0.244 (−1.100 to 0.612)	0.78 (0.33 to 1.85)	0.57	−0.230 (−1.759 to 1.300)	0.79 (0.17 to 3.67)	0.77
Indigenous	0.502 (−1.885 to 2.890)	1.65 (0.15 to 17.99)	0.68	1.745 (−0.832 to 4.322)	5.73 (0.44 to 75.37)	0.18
Mixed	0.455 (−0.107 to 1.018)	1.58 (0.90 to 2.77)	0.11	0.757 (−0.084 to 1.597)	2.13 (0.92 to 4.94)	0.08
Child sex						
Male		Referent			Referent	
Female	−0.129 (−0.427 to 0.169)	0.88 (0.65 to 1.18)	0.40	−0.216 (−0.737 to 0.305)	0.81 (0.48 to 1.36)	0.42
Child's age, months†						
12–15	0.215 (0.005 to 0.425)	1.24 (1.01 to 1.53)	0.04*	0.274 (−0.057 to 0.605)	1.31 (0.94 to 1.83)	0.10
15–18	−0.078 (−0.257 to 0.101)	0.92 (0.77 to 1.11)	0.39	−0.292 (−0.588 to 0.004)	0.75 (0.56 to 1.00)	0.05
18–24	−0.009 (−0.083 to 0.065)	0.99 (0.92 to 1.07)	0.81	−0.003 (−0.135 to 0.129)	1.00 (0.87 to 1.14)	0.97
24–38	−0.111 (−0.158 to -0.066)	0.89 (0.85 to 0.94)	<0.0001*	−0.206 (−0.344 to −0.068)	0.81 (0.71 to 0.93)	0.003*
CRP level, mg/L	−0.387 (−0.597 to −0.177)	0.68 (0.55 to 0.84)	0.0003*	−0.114 (−0.353 to 0.125)	0.89 (0.70 to 1.13)	0.35
zBMI	0.126 (−0.020 to 0.271)	1.13 (0.98 to 1.31)	0.09	0.086 (−0.172 to 0.343)	1.09 (0.84 to 1.41)	0.51
Birth weight, kg						
≥2.5		Referent			Referent	
<2.5	0.266 (−0.222 to 0.754)	1.31 (0.80 to 2.13)	0.28	−0.361 (−1.365 to 0.643)	0.70 (0.26 to 1.90)	0.48
Maternal education						
Post-Secondary		Referent			Referent	
No post-secondary	0.174 (−0.402 to 0.751)	1.19 (0.67 to 2.12)	0.55	1.204 (0.415 to 1.992)	3.33 (1.51 to 7.33)	0.003*
Family income (CAN $)						
$80 000+		Referent			Referent	
$30 000–$79 999	−0.305 (−0.763 to 0.152)	0.74 (0.47 to 1.16)	0.19	−0.425 (−1.249 to 0.399)	0.65 (0.29 to 1.49)	0.31
Less than $30 000	0.647 (0.032 to 1.261)	1.91 (1.03 to 3.53)	0.04*	0.552 (−0.368 to 1.471)	1.74 (0.69 to 4.36)	0.24
Breastfeeding Duration, months‡	0.051 (0.025 to 0.076)	1.05 (1.03 to 1.08)	0.0001*	0.057 (0.008 to 0.105)	1.06 (1.01 to 1.11)	0.02†

Continued

Table 4 Continued

Variable	Iron deficiency (ID) ß (95% CI)	OR (95% CI)	P value	Iron deficiency Anaemia (IDA) ß (95% CI)	OR (95% CI)	P value
Bottle Use >15 months						
No		Referent			Referent	
Yes	0.099 (−0.280 to 0.478)	1.10 (0.76 to 1.61)	0.61	0.437 (−0.251 to 1.125)	1.55 (0.78 to 3.08)	0.21
Current infant formula use						
No		Referent			Referent	
Yes	−2.256 (−3.303 to −1.209)	0.10 (0.04 to 0.30)	<0.0001†	−1.949 (−3.418 to −0.480)	0.14 (0.03 to 0.62)	0.009*
Cow's milk consumption						
Two cups (500 mL) or less		Referent			Referent	
More than two cups (500 mL)	0.474 (0.153 to 0.795)	1.61 (1.17 to 2.21)	0.004*	−0.084 (−0.676 to 0.508)	0.92 (0.51 to 1.66)	0.78

All models adjusted for age, sex, zBMI, birth weight, maternal education, family income, CRP, breastfeeding duration (continuous variable), cow's milk >2 cups, bottle use >15 months, infant formula use (Y/N).
*Statistically significant findings at p<0.05.
†Restricted cubic spline (RCS) analysis was used for child age.
‡Breastfeeding duration was included in model as a continuous variable.
CRP, C reactive protein; zBMI, body mass index z score.

to 6.58, p=0.01) and African and Caribbean (OR 3.37, 95% CI 1.65 to 6.90, p=0.0009) maternal ethnicities had higher odds of current formula use. Children of mixed maternal ethnicity had shorter breastfeeding duration (OR 0.61, 95% CI 0.39 to 0.93, p=0.02) compared with children of European maternal ethnicity.

DISCUSSION

In this study of young healthy children 1–3 years of age living in Toronto, Canada, we found that children of South Asian and West Asian/North African maternal ethnicities had higher odds of ID, while children of East Asian maternal ethnicity had lower odds of ID when compared with children of European maternal ethnicity. While the overall prevalence of ID was 12.2% in our cohort, the prevalence differed by maternal ethnicity: 20.1% South Asian, 20.9% West Asian/North African and 4.8% East Asian.

Regarding infant feeding practices considered risk factors for ID in young children, we found that children of South Asian maternal ethnicity had higher odds of bottle use beyond 15 months of age, and lower odds of meat consumption in the last 3 days, which may partly explain the higher prevalence of ID among children of South Asian maternal ethnicity. Children of West Asian/North African maternal ethnicity were not found to have higher odds of infant feeding practices considered risk factors of ID. There may be other risk factors we did not examine that may explain the higher prevalence of ID among this group.

There are no nationally representative data of iron status for Canadian children under 3 years of age.[29] However, a published review of 10 studies suggests a prevalence of ID ranging from 12% to 63.5%, and for IDA ranging from 1.3% to 79%, depending on the study population, child age and year.[4] Many of these studies focused on remote Indigenous communities across Canada, which had high prevalence of childhood ID and IDA.[30–34] The lack of access to nutritious and affordable iron-rich foods in these remote communities has been identified as a key determinant of this high prevalence.[30 33 35] The other studies focused on children living in urban Canadian settings, but these studies are now more than 20 years old.[10 35–38] Given the changes in Canadian demographics, current data are needed.[17] Our contemporary cohort demonstrates that while ID is a preventable micronutrient deficiency, it remains persistent among urban Canadian children.

Only one previous Canadian study focused on the association between maternal ethnicity and ID in urban children, and was published more than 30 years ago.[10] This study was conducted within a cohort of Chinese children with predominantly immigrant parents, and identified a prevalence of ID of 12.1%. Among infants 6 to 12 months of age, ID was more common in those who were breastfed compared with those who were formula-fed. The authors speculated that excessive amounts of cow's milk before

Table 5 Multivariable logistic regression model for the association between maternal ethnicity and infant feeding practices

	Breastfeeding >12 months		Cow's milk >2 cups		Bottle use >15 months		Meat consumption		Infant formula use	
Variable	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**
Maternal ethnicity										
European	Referent		Referent		Referent		Referent		Referent	
East Asian	1.03 (0.67 to 1.59)	0.89	0.91 (0.56 to 1.50)	0.71	0.88 (0.50 to 1.55)	0.67	6.82 (0.46 to 101.39)	0.16	1.25 (0.59 to 2.67)	0.56
Southeast Asian	1.33 (0.75 to 2.39)	0.33	1.54 (0.87 to 2.73)	0.14	1.53 (0.75 to 3.12)	0.25	0.60 (0.19 to 1.85)	0.37	2.85 (1.24 to 6.58)	0.01*
South Asian	0.86 (0.59 to 1.26)	0.44	1.26 (0.86 to 1.85)	0.23	2.37 (1.48 to 3.81)	0.0003*	0.32 (0.17 to 0.60)	0.0004*	1.09 (0.58 to 2.05)	0.79
West Asian/ North African	0.74 (0.38 to 1.44)	0.38	0.98 (0.47 to 2.08)	0.96	1.54 (0.59 to 4.01)	0.37	1.06 (0.21 to 5.43)	0.94	1.71 (0.71 to 4.12)	0.23
African and Caribbean	0.81 (0.47 to 1.41)	0.46	1.35 (0.79 to 2.31)	0.28	1.19 (0.61 to 2.34)	0.61	0.47 (0.18 to 1.22)	0.12	3.37 (1.65 to 6.90)	0.0009*
Latin American	0.63 (0.34 to 1.15)	0.13	1.11 (0.61 to 2.05)	0.72	2.00 (0.95 to 4.21)	0.07	1.36 (0.27 to 6.89)	0.71	0.92 (0.34 to 2.55)	0.88
Indigenous	3.19 (0.33 to 30.49)	0.31	1.55 (0.25 to 9.66)	0.64	6.40 (0.42 to 98.21)	0.18	0.46 (0.02 to 9.88)	0.62	2.49 (0.32 to 19.53)	0.39
Mixed	0.61 (0.39 to 0.93)	0.02*	0.72 (0.43 to 1.21)	0.21	0.99 (0.58 to 1.68)	0.96	0.67 (0.27 to 1.66)	0.39	1.42 (0.72 to 2.80)	0.31

Models were adjusted for the following covariates: breastfeeding >12 months as outcome—age, sex, zBMI, birth weight, maternal education, family income, cow's milk >2 cups, bottle use >15 months, infant formula use (Y/N); cow's milk >2 cups as outcome—age, sex, zBMI, birth weight, maternal education, family income, breastfeeding duration (continuous variable), bottle use >15 months, infant formula use (Y/N); bottle use >15 months as outcome—age, sex, zBMI, birth weight, maternal education, family income, breastfeeding duration (continuous variable), cow's milk >2 cups, infant formula use (Y/N); meat consumption (Y) as outcome—age, sex, zBMI, birth weight, maternal education, family income, breastfeeding duration (continuous variable), cow's milk >2 cups, bottle use >15 months, infant formula use (Y/N); infant formula use (Y) as outcome—age, sex, zBMI, birth weight, maternal education, family income, breastfeeding duration (continuous variable), cow's milk >2 cups, bottle use >15 months. Restricted cubic spline analysis was used for child age.

*Statistically significant findings at p<0.05.

zBMI, body mass index z score.

12 months of age contributed to the development of ID. In contrast, in our contemporary cohort, controlling for sociodemographic factors, the prevalence of ID was lowest among children of East Asian maternal ethnicity, and feeding practices were not significantly different from those of the European maternal ethnic group.

The few studies examining the association between maternal ethnicity and iron status in children living in other high income, ethnically diverse countries such as the UK and USA were also conducted decades ago. In the UK, D'Souza *et al* found that serum ferritin levels were lower in children of West Indian and Asian ethnicity, compared with Caucasian children in a small study conducted more than 30 years ago.[11] In another UK study, Lawson *et al* sampled 2-year old children (n=1057) of South Asian parents (Pakistani, Bangladeshi, Indian) 25 years ago.[12] Approximately 40% had ID, with risk factors including volume of cow's milk consumed, use of a bottle and mother's birth outside of the UK.

In the USA, Brotanek and colleagues examined ID in children 1 to 3 years, with data from more than 15 years ago.[13–16] Secular trends in prevalence were examined across three racial groups (non-Hispanic white, non-Hispanic black and Hispanic) using data from the US National Health and Nutrition Examination Survey, over three survey waves (1976 and 2002).[16] ID prevalence remained unchanged in non-Hispanic white children at about 6%; unchanged and persistently higher in Hispanic children at about 15%; and decreasing in non-Hispanic black children from approximately 15% to 6% (approximating non-Hispanic white children). Risk factors for the higher prevalence in children of Hispanic race/ethnicity were obesity, not attending daycare and prolonged bottle use.[13–16]

Therefore, the literature suggests that while the ethnic origins of populations in Canada, the UK and the USA may differ; ID in early childhood remains prevalent. The relationships with maternal ethnicity may also differ; however, several factors appear to be associated with ID across countries and over time. In our current Canadian cohort, we have previously identified several infant feeding practices and nutritional factors associated with increased odds of ID including bottle feeding beyond the first year of life, cow's milk intake greater than two cups per day, longer total breastfeeding duration, consumption of meat and meat alternatives less than two times per day, and higher body mass index.[5–9 25]

Strengths of this study include the use of a large sample of healthy children attending a scheduled health supervision visit. Additionally, we included covariates, to adjust for potential confounding and used multiple imputation to address missing covariate data. There are limitations to this study that should be acknowledged. First, although this was a multiethnic cohort, children with non-European maternal ethnicity accounted for approximately 35% of the cohort, compared with 51.5% of the population of Toronto, according to the Canadian census.[17] However, our cohort included children with a range of maternal ethnicities, including the largest groups represented in the City of Toronto. Second, we excluded parents who were unable to communicate in English, which may have underestimated the effect of maternal ethnicity. However, less than 7% of children were ineligible to participate in the TARGet Kids! cohort on the basis of a language barrier.[18] Finally, the responses to questions regarding infant feeding practices were parent-reported, raising the possibility of recall bias. However, our parent-reported responses are likely valid and reliable given the short recall period (less than 3 years).[26]

Findings from our study have implications for practice and policy. With many Western countries becoming increasingly diverse, understanding differences in health outcomes by maternal ethnicity will allow for increased cultural competency among healthcare professionals providing care for infants. Examining the associations between ethnicity and health outcomes will also allow for the identification of groups with higher risks of developing disease.[39] Culturally tailored health promotion practices will not only allow for a better understanding of a child's health outcomes but will also increase trust and open communication between parents and healthcare providers.[40]

CONCLUSION

Children of South Asian and West Asian/Northern African maternal ethnicities had an increased odds of ID. Feeding practices linked to ID were found in children of South Asian maternal ethnicity, but not in children of West Asian/North African maternal ethnicity. Findings from our study may inform future research examining whether infant feeding practices are mediating variables between maternal ethnicity and iron status. Raising clinicians' awareness about the high prevalence of ID among South Asian and West Asian/Northern African children, and targeted, culturally tailored approaches to providing guidance to parents of young children on healthy feeding practices may be important strategies in preventing ID in early childhood.

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