Perinatal and Early Childhood Factors for Overweight and Obesity in Young Canadian Children

Yipu Shi, MD, PhD, Margaret de Groh, PhD, Howard Morrison, PhD

ABSTRACT

BACKGROUND: This study assessed potential early-life factors and their interrelationships with obesity among young Canadian children.

METHODS: Data from a nationally representative sample of children aged 6 to 11 years in the Canadian Health Measures Survey were analyzed. The associations of perinatal and early childhood behaviours and socio-economic factors with overweight or obesity were evaluated using multivariate logistic regression models. Adjusted population attributable risk fractions (PARFs) were calculated using multivariate logistic regression models.

RESULTS: Of 968 term-born children, 21% were overweight and another 13% were obese. Maternal smoking during pregnancy (adjusted odds ratio, 2.26; 95% confidence interval, 1.23-4.15) was positively associated with obesity. This association was mediated by birth weight (suppression effect); once controlled, the strength of the association between smoking and child obesity increased by 12%. Birth weight per 100 g (1.05; 1.005-1.09) was significantly associated with obesity. Exclusive breastfeeding for 6 months (0.44; 0.31-0.61), adequate sleep hours (0.39; 0.16-0.94) and being physically active (0.50; 0.26-0.93) were found to be protective. Breastfeeding, whether exclusive or not, significantly reduced obesity risk among children whose mothers never smoked in pregnancy. PARFs indicated that 24.4%, 11.5%, 11.3% and 6.0% prevalent cases of child obesity might be prevented by exclusive breastfeeding, smoking cessation during pregnancy, adequate sleep during childhood, and avoiding high birth weight, respectively.

CONCLUSIONS: This study identified multiple perinatal and childhood factors associated with obesity in young Canadian children. Effective prevention strategies targeting four modifiable maternal and child risk factors may reduce childhood obesity by up to 54% in Canada.

KEY WORDS: Childhood obesity; birth weight; maternal smoking; breastfeeding; Canadian Health Measures Survey

La traduction du résumé se trouve à la fin de l'article.

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It is estimated that one in three Canadian children and adolescents are either overweight or obese.[1] Not only are obese children at an increased risk of developing serious medical and psychological complications, they are also likely to stay obese into adolescence and adulthood.[2,3] Moreover, if begun in childhood, obesity in adulthood is likely to be more severe.[4] Therefore, it is important to identify early modifiable determinants of childhood obesity to help develop effective prevention practices.

Studies exploring early life determinants of childhood obesity have found that genetic and maternal factors, birth weight, infant growth and feeding, childhood behaviours and environmental factors are associated with obesity.[5] Current evidence suggests that high birth weight is associated with increased risk of obesity, and that birth weight may serve as a mediator between parental influences and later disease risk.[6] Maternal smoking in pregnancy is another factor associated with childhood obesity risk.[7] The exact mechanisms by which maternal smoking may influence early weight gain are not yet well understood, although it has been hypothesized that smoking-induced low birth weight and subsequent catch-up growth may lie on the causal pathway. Alternatively, maternal smoking may be a proxy measure of socio-economic inequalities, and reflect residual confounding after other markers for socio-economic status are controlled.[7] Although the smoking rate in Canada has declined substantially over the past decade, smoking remains common among women of childbearing age.[8]

Though results have been mixed, there is evidence to suggest breastfeeding may protect against childhood obesity.[9] Different studies have reported that the protective effect of breastfeeding is confined to certain population subgroups, or modified by maternal or child characteristics, or due to residual confounding.[10-12] Nevertheless, it is useful to have observational studies evaluating the effect of breastfeeding on the risk of obesity in the presence of key pre- and postnatal factors to inform the design of strategies for intensive interventions.

The Canadian Health Measures Survey (CHMS) is a comprehensive nationally representative survey with information from biological mothers on pregnancy, birth and breastfeeding, and anthropometric measures and other factors for children aged 6 to 11.[13-15] Because decision making requires not only the strength of the association, but also the prevalence of exposure, this can be best provided by estimating population attributable risk fraction (PARF). The objectives of this study were to assess the independent effects of early-life factors of childhood obesity and the population health impact of potential interventions targeting these factors.

Author Affiliations

Social Determinants and Science Integration Directorate, Public Health Agency of Canada, Ottwa, ON

Correspondence: Yipu Shi, Social Determinants and Science Integration Directorate, Public Health Agency of Canada, 785 Carling Ave, 9th floor, Ottawa, ON K1A 0K9, Tel: 613-941-2436, Fax: 613-960-0921, E-mail: yipu.shi@phac-aspc.gc.ca

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METHODS

Study design and study population

We used data from the CHMS cycle 1 (2007-2009), a complex, multistage sampling survey designed to collect data on self-reported and direct measures of health and wellness from a representative sample of approximately 5,600 Canadians aged 6 to 79 years. The CHMS covers approximately 96.3% of the Canadian population. Health Canada's Research Ethics Board reviewed and approved all processes and protocols for the CHMS. Informed consent was obtained from all participants. A household interview collected general demographic information and responses to an in-depth health questionnaire. A visit to a mobile examination centre (clinic) collected anthropometric measurements and blood and urine samples. Overall, the combined response rate was 51.7%. A detailed description of the survey can be found elsewhere.[16]

The focus of this study was on children aged 6 to 11. The CHMS cycle 1 included 1,074 children in this age range. We excluded 35 children whose birth weight was not provided and 2 whose weight and height were not recorded. We also excluded 56 children considered to be pre-term births (gestational age <37 weeks), and 13 whose birth weight was <1500 g because their growth patterns and risk of obesity may differ from term-birth children.[17] Thus, a total of 968 children were included in the final analyses.

Perinatal and childhood behaviours and socio-economic factors

The child's biological parent (usually the mother) provided information on pregnancy, birth and breastfeeding. Birth information included maternal age at birth (defined as the age of a child's biological mother when the child was born and classified into three groups: 15-24, 25-35, and >35 years); child's weight at birth (in grams); number of days before or after the due date that the child was born. For those who smoked during the pregnancy, the average number of cigarettes smoked per day during the first, second and third trimester or throughout the pregnancy was collected. Duration and exclusiveness of the child's breastfeeding experience was categorized into one of three groups: exclusively breastfed for 6 months or longer; some breastfeeding; not breastfed at all. The child's physical activity level was determined by asking, "Over the past 7 days, on how many days was [the child] physically active for a total of at least 60 minutes per day?" Those who answered 4 days or more were considered physically active, and those who reported 3 days or less were classified as inactive. Sleep time refers to the number of hours usually spent sleeping in a 24-hour period. This measure was categorized into less than 8 hours, 8 to 10 hours, or more than 10 hours. Education level was based on the highest education level for the household (post-secondary degrees, secondary or less). Household income was classified into low/middle and high income groups, based on total income from all sources and the number of people living in a household. Two categories for ethnicity were used: Whites; and non-Whites, which included Aboriginals living off reserve.

Physical measures

During the clinic visit, standing height and weight were measured and used to calculate body mass index (BMI). Age- and sex-adjusted BMI z-scores (BMIZ) were developed based on World Health Organization (WHO) child growth standards for 5-19 year olds.[18] According to WHO, childhood obesity is defined as a BMIZ that is more than two standard deviations (SDs) above the mean (≈97.7th percentile) and overweight is defined as a BMIZ between one and two SDs above the mean (≈84th to 97.7th percentile) of the standard population.

Table 1. Characteristics of Canadian Children 6 to 11 Years of Age (CHMS Cycle 1, 2007-2009)

	Study Sample‡	Population-weighted Percentages or Means (Standard errors)
Age, years	968	8.6 (0.09)
Sex		
Boys	489	50.3 (0.6)
Girls	479	49.7 (0.6)
Ethnicity		
White	750	75.8 (6.0)
Non-White	217	23.8 (6.1)*
Weight status†		
Normal or underweight	665	66.3 (1.8)
Overweight	182	20.7 (2.3)
Obese	121	13.0 (1.3)
Maternal age at birth, years		
<25	182	18.2 (1.5)
25-35	651	68.7 (1.7)
>35	133	12.7 (2.1)
Maternal smoking during pregnancy		
No	823	83.2 (1.8)
<5 cigarettes per day	40	4.5 (0.7)
≥5 cigarettes per day	105	12.3 (1.7)
Birth weight, grams	968	3471 (21)
Breastfeeding over 6 months		
Yes, exclusively	448	45.9 (2.9)
Yes, not exclusively	324	34.6 (2.0)
No	196	19.5 (1.6)
Highest household education		
Post-secondary	782	80.2 (2.9)
Less than post-secondary	186	19.9 (2.8)
Household income		
Low/lower middle	233	25.6 (2.8)
Upper middle	265	26.2 (2.1)
High	446	45.4 (2.6)
60 mins physical activity per day, days/week		
≥4	813	83.4 (1.4)
<4	155	16.5 (1.4)
Amount of sleep per day, hours		
<8	101	10.4 (1.6)
8-10	288	28.8 (1.6)
>10	579	60.8 (1.9)

* Coefficient of variation, 16.6%-33.3% – interpret with caution.
† Estimated using WHO child growth standard.
‡ Samples for Ethnicity, Maternal age at birth and Household income did not add up to 968 due to missing values on these variables.

Statistical analyses

We compared the prevalence of normal weight, overweight and obesity by sample characteristics including sex, ethnicity, mother's age at birth, maternal smoking during pregnancy, breastfeeding experience, levels of physical activity, sleep time, household education and income. For continuous variables, mean age, mean birth weight, and mean BMI were compared according to weight status. Differences in percentages and means between groups were determined using t-tests. Statistical significance was defined as a p-value <0.05.

We assessed the association of childhood overweight and obesity with related variables using a logistic regression model. First, univariate analyses were performed. Second, multivariate analyses were performed that included all variables that were significantly ($p<0.05$) or borderline significantly ($p<0.1$) associated with over-

Table 2. Children's Demographics and Selected Perinatal and Childhood Characteristics by Weight Status (CHMS cycle 1, 2007-2009)

	Sample§	Population-weighted Percentages or Means (95% confidence interval)		
		Normal Weight	Overweight	Obese
Mean age, years	968	8.5 (8.2-8.7)	9.0 (8.6-9.4)	8.7 (8.2-9.2)
Sex				
Boys	489	62.4 (56.7-68.1)	20.8 (15.0-26.5)	16.8 (13.7-20.0)*
Girls	479	70.3 (65.1-75.5)	20.5 (15.1-25.9)	9.2 (4.7-13.7)†
Mean birth weight, grams	968	3439 (3389-3489)	3533 (3434-3632)	3532 (3455-3608)
Maternal age at birth, years				
<25	182	61.8 (49.8-73.8)*	20.9 (16.0-25.8)*	17.2 (4.6-29.9)†*
25-35‡	651	67.6 (60.3-74.8)	20.8 (13.0-28.6)†	11.6 (7.9-15.3)
>35	133	65.3 (57.5-73.0)*	19.9 (12.7-27.2)*	14.8 (5.0-24.5)†*
Maternal smoking during pregnancy				
No	823	69.0 (64.0-74.1)*	19.4 (14.5-24.3)*	11.6 (8.8-14.4)*
Yes	145	52.9 (42.0-63.8)*	27.0 (13.2-40.9)†*	20.1 (10.5-29.6)†*
Breastfeeding over 6 months				
Exclusively	448	71.5 (64.4-78.7)*	20.2 (12.6-27.7)†*	8.3 (4.4-12.1)†*
Not exclusively	324	61.6 (54.6-68.7)*	21.1 (14.7-27.5)*	17.2 (11.4-23.0)*
No‡	196	62.3 (56.7-67.9)	20.9 (15.0-26.8)	16.8 (11.3-22.2)
Highest household education				
Post-secondary degrees	782	67.6 (62.8-72.5)*	19.6 (14.7-24.5)*	12.7 (10.2-15.2)*
Secondary or less	186	60.9 (51.4-70.5)*	24.9 (15.6-34.2)†*	14.2 (3.9-24.5)†*
Household income				
Low and middle	498	62.5 (59.1-65.9)	22.6 (15.3-29.9)	14.9 (9.3-20.5)†
High‡	446	71.0 (64.1-77.9)	18.3 (13.4-23.2)	10.7 (5.9-15.5)†
Ethnic background				
Whites	750	67.0 (62.4-71.6)	21.6 (16.9-26.4)	11.4 (8.7-14.0)
Non-Whites	217	63.7 (56.5-70.9)	17.9 (10.3-25.5)†	18.4 (11.1-25.6)†
60 min physical activity per day, days/week				
<4	155	56.9 (43.1-70.7)*	28.4 (17.0-39.9)†*	14.7 (9.9-19.5)*
≥4	813	68.2 (65.6-70.8)*	19.1 (14.5-23.8)*	12.7 (9.5-15.9)*
Amount of sleep per day, hours				
<8‡	101	57.2 (44.7-69.7)	22.3 (10.1-34.6)†	20.4 (11.4-29.5)†
8-10	288	65.2 (58.0-72.4)*	18.9 (14.3-23.4)*	15.9 (10.7-21.1)*
>10	579	68.4 (63.3-73.5)*	21.2 (14.1-28.3)*	10.4 (7.2-13.6)*

* $p<0.05$, differences in prevalence were determined using t-test.
† Coefficient of variation, 16.6%-33.3% – interpret with caution.
‡ Reference group for multiple comparisons within a variable.
§ Samples for Ethnicity, Maternal age at birth and Household income did not add up to 968 due to missing values on these variables.

weight or obesity in univariate analyses. Because birth weight may lie within the causal pathway between maternal smoking and childhood obesity, we analyzed multivariate model 1 without birth weight to estimate the total effect of maternal smoking on child obesity; model 2 examined how the inclusion of birth weight affected the above associations. The magnitude of any mediation effects was calculated with the formula: [(coefficient (model 1) – coefficient (model 2))/coefficient (model 2)]*100. Based on previous research, an effect >10% was considered meaningful.[19] To test the hypothesis that any effect of breastfeeding on child obesity may be modified by maternal smoking, we stratified the analysis by mother's smoking status during pregnancy.

The PARFs for obesity and overweight were calculated to estimate the proportion of obesity or overweight in young children that could theoretically be prevented by eliminating a specific causal factor. Conventional unadjusted PARFs are easy to calculate, but may overestimate the preventable potential of risk factors. Thus, PARFs should be estimated using multivariate regression models adjusted for confounding factors.[20,21] To assess PARFs of categorical variables for obesity, the expected number of obese children was predicted by summing up the predicted number of obese cases among children 1) unexposed to the risk factor of interest and 2) exposed to risk factor, but had it removed by setting it to zero in the multivariate regression models. The multivariate regression models contained the following predictors: child's age, sex, ethnicity, birth weight, maternal smoking in pregnancy, breastfeeding, child's physical activity, and duration of sleep. PARFs were calculated by applying the formula PARF = (observed no. of obese – expected no. of obese after removal of the exposure)/observed no. of obese. For continuous variables, such as birth weight, removal of exposure to large birth weight was estimated by setting individuals with large birth weight (>4000 g) to the mean birth weight of individuals with "normal" birth weight (≤4000 g), which was 3346 g in our sample. The same approach was used to calculate PARFs for overweight.

All estimates were obtained using sampling weights produced by Statistics Canada to account for design effect and non-response bias. Variance for means, proportions and coefficients of regression parameters was estimated using bootstrap method with 11 degrees of freedom, as recommended by Statistics Canada for cycle 1 of the CHMS.[22] The analyses were performed using SAS Enterprise Guide 4 (SAS Institute Inc., Cary, NC) and SUDAAN 10.0.1 (RTI International, Research Triangle Park, NC).

RESULTS

The characteristics of the children in this study are summarized in Table 1. The prevalence of overweight and obesity was 21% (95% CI: 15.6-25.7) and 13% (95% CI: 10.1-15.9), respectively. Mean birth weight was 3471 g. Seventeen percent were exposed to maternal cigarette smoke in utero. Almost one half (46%) were exclusively breastfed for 6 months or longer. Only 20% were never breastfed at all. About 20% of children were from households without post-secondary degrees, 45% were from families with high income, and 76% were White. The majority (83%) were physically active, and 60% slept 10 hours or more daily.

Those children less likely to have normal weight were boys, children born to younger mothers (<25 years), children whose mothers smoked during pregnancy, and children born to parents with no post-secondary degree/diplomas. Children who were exclusively

Table 3. Unadjusted and Multivariate Model Adjusted Odds Ratios (OR) of Overweight or Obese

	Unadjusted ORs		Adjusted ORs (model 1)		Adjusted ORs (model 2)	
	Overweight	**Obese**	**Overweight**	**Obese**	**Overweight**	**Obese**
Age, years	**1.20 (1.00-1.43)**	1.08 (0.93-1.26)	**1.21 (1.00-1.46)**	1.08 (0.89-1.31)	**1.23 (1.02-1.49)**	1.10 (0.91-1.35)
Sex						
Girls	1	1	1	1	1	1
Boys	1.14 (0.81-1.60)	**2.07 (1.18-3.65)**	1.14 (0.80-1.62)	**1.97 (1.01-3.87)**	1.04 (0.69-1.56)	1.78 (0.88-3.64)
Ethnicity						
Whites	1	1	1	1	1	1
Non-Whites	0.87 (0.59-1.29)	1.70 (0.96-3.01)	0.92 (0.61-1.40)	1.70 (0.96-3.03)	1.01 (0.69-1.47)	**1.81 (0.97-3.41)**
Maternal smoking during pregnancy						
No	1	1	1	1	1	1
Yes	1.82 (0.82-4.06)	**2.26 (1.18-4.31)**	**2.01 (0.97-4.16)**	**2.26 (1.23-4.15)**	**2.25 (0.98-5.15)**	**2.41 (1.33-4.36)**
Birth weight (per 100 g)	**1.04 (0.996-1.08)**	**1.04 (1.004-1.08)**	–	–	**1.06 (1.01-1.11)**	**1.05 (1.005-1.09)**
Exclusive breastfeeding for 6 months						
No	1	1	1	1	1	1
Exclusively	0.84 (0.40-1.76)	**0.43 (0.32-0.58)**	0.90 (0.44-1.84)	**0.45 (0.32-0.63)**	0.87 (0.43-1.77)	**0.44 (0.31-0.63)**
Not exclusively	1.02 (0.55-1.91)	1.04 (0.54-2.00)	0.97 (0.52-1.82)	0.90 (0.45-1.77)	0.95 (0.51-1.78)	0.89 (0.45-1.76)
60 min physical activity per day, days/week						
<4	1	1	1	1	1	1
≥4	0.56 (0.31-1.01)	0.72 (0.42-1.23)	**0.53 (0.28-0.99)**	0.68 (0.37-1.25)	**0.50 (0.25-0.99)**	0.71 (0.38-1.29)
Amount of sleep, per day, hours						
<8	1	1	1	1	1	1
8-10	0.74 (0.29-1.89)	0.68 (0.30-1.57)	0.77 (0.31-1.91)	0.60 (0.23-1.60)	0.75 (0.31-1.79)	0.56 (0.20-1.59)
>10	0.80 (0.33-1.90)	**0.42 (0.24-0.76)**	0.97 (0.46-2.04)	0.43 (0.18-1.03)	1.00 (0.48-2.10)	**0.41 (0.16-1.02)**
Household income						
High	1	1	–	–	–	–
Low and middle	1.41 (0.92-2.16)	1.58 (0.72-3.44)	–	–	–	–
Highest household education						
Post-secondary degrees	1	1	–	–	–	–
Secondary or less	1.41 (0.83-2.37)	1.24 (0.48-3.19)	–	–	–	

Model 1: adjusted for age, sex, ethnicity, maternal smoking during pregnancy, breastfeeding experience, physical activity.
Model 2: adjusted for model 1 + birth weight.

breastfed for at least 6 months, physically active, and usually receiving over 10 hours per day of sleep were less likely to be obese. Differences in demographics and perinatal and childhood characteristics by weight status are shown in Table 2.

Because neither household income nor education was associated with either overweight or obesity in univariate or multivariate analyses (Table 3), they were not included in the final multivariate models summarized here. In the multivariate analyses (Model 1), maternal smoking (OR 2.26; 95% CI: 1.23-4.15) and being a boy increased the risk of obesity, whereas exclusive breastfeeding for 6 months (0.45; 0.32-0.63) was protective. As expected, mean birth weight was significantly lower for children whose mothers smoked during pregnancy (3334 g) than for those whose mothers did not (3498 g). As shown in model 2, adjustment for birth weight led to a 12% increase in the odds ratio for obesity with maternal smoking (2.41; 1.33-4.36). Every 100 g increase in birth weight was also positively and independently associated with a 5% increase in child obesity risk (1.05; 1.005-1.09). Among other findings, child's age increased and physical activity decreased the risk of being overweight. Being White and receiving adequate sleep time (>10 hrs) were of borderline significance, suggesting a lowered risk of obesity.

Only 17% of the children in our study were born to mothers who smoked during pregnancy. Consequently, we were only able to evaluate the impact of breastfeeding on weight status among children born to non-smoking mothers. After adjustment for child's age, sex, ethnicity, birth weight, household education and income, regular physical activity and sleep time, a dose-response relationship for breastfeeding with obesity emerged among children born to non-smoking mothers. Compared to children who were never breastfed, the risk of obesity was reduced by as much as 75% in children exclusively breastfed at least 6 months, and by 50% in children not exclusively breastfed (Table 4).

Finally, we estimated the PARFs for key modifiable factors, including not exclusive breastfeeding or not breastfed (24.4%), maternal smoking during pregnancy (11.5%), short duration of sleep (<8 hrs; 11.3%) and large birth weight (>4000 g; 6.7%). A combined PARF for all four risk factors suggested 54% of obesity in children could be prevented by removing these risk factors (Table 5).

DISCUSSION

Rising rates of obesity and overweight in young children have increased efforts to identify early life risk and protective factors to guide early intervention practices. In a nationally representative sample of Canadian children aged 6 to 11 years, we found that one third were either overweight or obese. Our data confirm associations of multiple perinatal and childhood factors with obesity. Elevated risks for obesity were observed for maternal smoking during pregnancy, birth weight, being non-White and age, whereas exclusive breastfeeding, adequate sleep and being physically active were found to be protective. Birth weight partially mediates (suppression) the effect of maternal smoking on obesity. Among children whose mothers never smoked during pregnancy, breastfeeding, whether exclusive or not, further reduced obesity risk. With effective population health strategies that target modifiable factors of early life, 54% of child obesity may be prevented.

In this study, maternal smoking during pregnancy demonstrated a 2.4-fold increase in obesity risk, independent of birth weight. This result is in line with other studies across populations with markedly different demographic profiles and confounding structures,[7,23] though the etiology underlying this relationship is not well understood. Several mechanisms have been proposed, such as nicotine exposure-related low birth weight and catch-up growth, alterations in appetite, mediation effects of reduced leptin and other hormones, or epigenetic changes related to intrauterine tobacco exposure.[7] Our

Table 4. Multivariate Regression Models of Overweight or Obesity With Breastfeeding Among All Children and Children Born to Mothers Who Never Smoked During Pregnancy*

Breastfeeding for 6 months	All Subjects		Subgroup†	
	Overweight (ORs)	Obesity (ORs)	Overweight (ORs)	Obesity (ORs)
Exclusive	0.87 (0.43-1.77)	0.44 (0.31-0.63)	0.88 (0.39-1.97)	0.25 (0.14-0.44)
Not exclusive	0.95 (0.51-1.78)	0.89 (0.45-1.76)	0.91 (0.47-1.77)	0.51 (0.25-0.99)
No	1	1	1	1

* Sample size for children born to mothers who smoked in pregnancy was too small for reliable estimation.
† Subgroup: children born to mothers who never smoked in pregnancy.
Multivariate regression models were adjusted for: child's age, sex, ethnicity, birth weight, physical activity, duration of sleep and household education and income.

Table 5. Model-adjusted* Population Attributable Risk Fractions (PARFs) for Preventable Perinatal and Childhood Risk Factors of Childhood Obesity or Overweight

	Prevalence	Model-adjusted PARFs
Obesity		
Maternal smoking in pregnancy	16.8%	0.115
Large birth weight (>4000 g)	13.5%	0.067
Not exclusive breastfeeding	45.9%	0.244
Duration of sleep <8 hours	39.2%	0.113
Total preventable		0.539
Overweight		
Maternal smoking in pregnancy	16.8%	0.099
Large birth weight (>4000 g)	13.5%	0.028
Physically inactive	16.5%	0.088
Total preventable		0.215

* Variables contained in the multivariate regression models: child's age, sex, ethnicity, birth weight, maternal smoking in pregnancy, breastfeeding, child's physical activity and duration of sleep.

study also demonstrated a partial mediating effect of birth weight in the relationship between maternal smoking and obesity. Our results support a suppression effect such that maternal smoking during pregnancy may, on one hand, increase the risk of child obesity (perhaps by one or more of the above mechanisms), and on the other hand, indirectly reduce the risk of obesity by decreasing birth weight. Our results also suggest that birth weight only partially mediates obesity risk related to maternal smoking during pregnancy; the majority of the association between intrauterine tobacco exposure and later obesity is still largely birth weight independent.[7,24,25] Apart from possible biological effects of maternal smoking on offspring's body weight, maternal smoking may be a strong marker for socio-economic inequalities and unfavourable environmental exposures as smokers and their children tend to have less healthy lifestyles.[7] Although household education and income were examined and found to be unrelated to child overweight and obesity risk, residual confounding related to unmeasured socio-economic status remains a concern. Smoking cessation during pregnancy is and should continue to be promoted, and prenatal and postnatal support for more disadvantaged mothers remains a priority.

The positive linear association between birth weight and obesity observed in this study is consistent with the study of Reilly et al., who reported, in a longitudinal birth cohort, that every 100 g increase in birth weight was associated with an increased prevalence of obesity (OR 1.05; 95% CI: 1.03-1.38).[26] In Canada, mean birth weight for term-birth has increased for several decades, and this increase was thought largely the result of a rise in maternal prepregnancy obesity, gestational weight gain and gestational diabetes.[27] While preterm birth and very low birth weight are important public health concerns, in the era of the childhood obesity epidemic, maternal health providers should pay more attention to these maternal factors to prevent larger increases in the weight of infants born at or after term.

Another important finding in this study was the significant protective effect of exclusive breastfeeding on childhood obesity among children whose mothers did not smoke during pregnancy. We also observed that this protective effect extended to children who were not exclusively breastfed. This dose-response relationship is particularly meaningful because it helps to clarify the importance of this relationship once potential environmental and socio-economic influences commonly associated with maternal smoking behaviours (that may dilute any protective effect of breastfeeding on obesity) are excluded. Maternal smoking may not only be a proxy measure of disadvantaged socio-economic status, it may also be related to postnatal environment such as diet and other unhealthy behaviours including postnatal smoking, which is highly correlated with smoking during pregnancy.[28] A recent study suggests that ingestion of tobacco compounds via breast milk is associated with an elevation of child obesity risk.[29] Comparable results from another study conducted in a low socio-economic sample also found breastfeeding to be protective in offspring of non-smoking mothers.[11]

Strengths and limitations

A particular strength of this study is that our findings are based on a nationally representative sample of children, which facilitates the generalizability of our results. The total estimated preventable PARF is also generalizable for population health decision making for childhood obesity reduction. Our study is cross-sectional, with prenatal and postnatal information collected retrospectively, but within the context of a general health survey, suggesting that any bias is likely to be non-differential. Several studies have shown that mothers' retrospective recall of birth weight, gestational age, smoking history during pregnancy, and breastfeeding history is both reproducible and accurate for clinical and epidemiological research.[30]

One area of particular concern in this study is the comparatively high reported rate of exclusive breastfeeding for 6 months or longer (46%). In contrast, a national survey of Canadian women in 2006 found this rate to be only 14.4%.[31] Whether our results reflect a real improvement of women's breastfeeding practice in Canada, recall bias or the consequence of a comparatively affluent survey sample, requires confirmation. A comparison of the income distribution of the CHMS with other Canadian surveys indicated 10% more high-income households in our data. Notably, our result is comparable with some exclusive breastfeeding rates reported in US studies (35%-40%).[32] Other limitations include the lack of information on dietary intake during childhood that could have confounded the relationships between perinatal and early childhood factors and childhood obesity.

In conclusion, obesity remains prevalent among children of elementary school age. Public health interventions designed to pre-

vent childhood obesity should include components to encourage smoking cessation among pregnant women, healthy living to prevent high birth weight infants, and the promotion of exclusive breastfeeding for at least 6 months.

REFERENCES

1. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J Pediatr Obes* 2010;5(3):265-73.
2. Charney E, Goodman HC, McBride M, Lyon B, Pratt R. Childhood antecedents of adult obesity. Do chubby infants become obese adults? *N Engl J Med* 1976;295(1):6-9.
3. Shankaran S, Bann C, Das A, Lester B, Bada H, Bauer CR, et al. Risk for obesity in adolescence starts in early childhood. *J Perinatol* 2011;31(11):711-16.
4. Freedman DS, Khan LK, Dietz WH, Srinivasan SR, Berenson GS. Relationship of childhood obesity to coronary heart disease risk factors in adulthood: The Bogalusa Heart Study. *Pediatrics* 2001;108(3):712-18.
5. Monasta L, Batty GD, Cattaneo A, Lutje V, Ronfani L, van Lenthe FJ, et al. Early-life determinants of overweight and obesity: A review of systematic reviews. *Obes Rev* 2010;11(10):695-708.
6. Yu ZB, Han SP, Zhu GZ, Zhu C, Wang XJ, Cao XG, et al. Birth weight and subsequent risk of obesity: A systematic review and meta-analysis. *Obes Rev* 2011;12(7):525-42.
7. Oken E, Levitan EB, Gillman MW. Maternal smoking during pregnancy and child overweight: Systematic review and meta-analysis. *Int J Obes* (Lond) 2008;32(2):201-10.
8. Janz T. Current smoking trends. *Health at a Glance* June 2012. Available at: http://www.statcan.gc.ca/pub/82-624-x/2012001/article/11676-eng.pdf (Accessed August 22, 2012).
9. Arenz S, Rückerl R, Koletzko B, von Kries R. Breast-feeding and childhood obesity—A systematic review. *Int J Obesity* 2004;28(10):1247-56.
10. Beyerlein A, Toschke AM, von Kries R. Breastfeeding and childhood obesity: Shift of the entire BMI distribution or only the upper parts? *Obesity* (Silver Spring) 2008;16(12):2730-33.
11. Bogen DL, Hanusa BH, Whitaker RC. The effect of breast-feeding with and without formula use on the risk of obesity at 4 years of age. *Obes Res* 2004;12(9):1527-35.
12. Wadsworth M, Marshall S, Hardy R, Paul A. Breast feeding and obesity. Relation may be accounted for by social factors. *BMJ* 1999;319(7224):1576.
13. Prentice-Dunn H, Prentice-Dunn S. Physical activity, sedentary behavior, and childhood obesity: A review of cross-sectional studies. *Psychol Health Med* 2012;17(3):255-73.
14. Wells JC, Hallal PC, Reichert FF, Menezes AM, Araujo CL, Victora CG. Sleep patterns and television viewing in relation to obesity and blood pressure: Evidence from an adolescent Brazilian birth cohort. *Int J Obes* (Lond) 2008;32(7):1042-49.
15. Wijlaars LP, Johnson L, van Jaarsveld CH, Wardle J. Socioeconomic status and weight gain in early infancy. *Int J Obes* (Lond) 2011;35(7):963-70.
16. Tremblay MS, Gorber SC. Canadian Health Measures Survey: Brief overview. *Can J Public Health* 2007;98(6):453-56.
17. Casey PH, Kraemer HC, Bernbaum J, Yogman MW, Sells JC. Growth status and growth rates of a varied sample of low birth weight, preterm infants: A longitudinal cohort from birth to three years of age. *J Pediatr* 1991;119(4):599-605.
18. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull WHO* 2007;85(9):660-67.
19. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J Pers Soc Psychol* 1986;51(6):1173-82.
20. Benichou J. A review of adjusted estimators of attributable risk. *Stat Methods Med Res* 2001;10(3):195-216.
21. Toschke AM, Ruckinger S, Bohler E, von Kries R. Adjusted population attributable fractions and preventable potential of risk factors for childhood obesity. *Public Health Nutr* 2007;10(9):902-6.
22. Canadian Health Measures Survey. Data User Guide: Cycle 1. 2012. Available at: http://www23.statcan.gc.ca/imdb-bmdi/pub/document/5071_D2_T1_V1-eng.htm (Accessed November 9, 2012).
23. von Kries R, Toschke AM, Koletzko B, Slikker W, Jr. Maternal smoking during pregnancy and childhood obesity. *Am J Epidemiol* 2002;156(10):954-61.
24. Beyerlein A, Ruckinger S, Toschke AM, Schaffrath RA, von Kries R. Is low birth weight in the causal pathway of the association between maternal smoking in pregnancy and higher BMI in the offspring? *Eur J Epidemiol* 2011;26(5):413-20.
25. Sharma AJ, Cogswell ME, Li R. Dose-response associations between maternal smoking during pregnancy and subsequent childhood obesity: Effect modification by maternal race/ethnicity in a low-income US cohort. *Am J Epidemiol* 2008;168(9):995-1007.
26. Reilly JJ, Armstrong J, Dorosty AR, Emmett PM, Ness A, Rogers I, et al. Early life risk factors for obesity in childhood: Cohort study. *BMJ* 2005;330(7504):1357.
27. Kramer MS, Morin I, Yang H, Platt RW, Usher R, McNamara H, et al. Why are babies getting bigger? Temporal trends in fetal growth and its determinants. *J Pediatr* 2002;141(4):538-42.
28. Kahn RS, Certain L, Whitaker RC. A reexamination of smoking before, during, and after pregnancy. *Am J Public Health* 2002;92(11):1801-8.
29. Wen X, Shenassa ED, Paradis AD. Maternal smoking, breastfeeding, and risk of childhood overweight: Findings from a national cohort. *Matern Child Health J* 2012 Jun 20 (Epub ahead of print).
30. Tomeo CA, Rich-Edwards JW, Michels KB, Berkey CS, Hunter DJ, Frazier AL, et al. Reproducibility and validity of maternal recall of pregnancy-related events. *Epidemiology* 1999;10(6):774-77.
31. Chalmers B, Levitt C, Heaman M, O'Brien B, Sauve R, Kaczorowski J. Breastfeeding rates and hospital breastfeeding practices in Canada: A national survey of women. *Birth* 2009;36(2):122-32.
32. McDowell MM, Wang CY, Kennedy-Stephenson J. Breastfeeding in the United States: Findings from the National Health and Nutrition Examination Surveys, 1999-2006. *NCHS Data Brief* 2008;5:1-8.

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RÉSUMÉ

CONTEXTE : Nous avons évalué des facteurs potentiels au début de la vie et leurs rapports mutuels avec l'obésité chez de jeunes enfants canadiens.

MÉTHODE : Nous avons analysé les données d'un échantillon national représentatif d'enfants de 6 à 11 ans dans l'Enquête canadienne sur les mesures de la santé. À l'aide de modèles de régression logistique multivariée, nous avons évalué les associations entre les comportements durant la période périnatale et la petite enfance, certains facteurs socioéconomiques, le surpoids et l'obésité, puis calculé les fractions étiologiques du risque ajustées dans la population (FER_p).

RÉSULTATS : Sur 968 enfants nés à terme, 21 % étaient en surpoids et 13 % étaient obèses. Le tabagisme maternel durant la grossesse (rapport de cotes ajusté de 2,26; intervalle de confiance de 95 %, 1,23-4,15) était associé positivement à l'obésité. Cette association était assistée par le poids de naissance (effet de suppression); une fois les ajustements apportés, la force de l'association entre le tabagisme et l'obésité de l'enfant augmentait de 12 %. Le poids de naissance p. 100 g (1,05; 1,005-1,09) présentait une corrélation significative avec l'obésité. L'allaitement maternel exclusif pendant 6 mois (0,44; 0,31-0,61), les heures de sommeil suffisantes (0,39; 0,16-0,94) et l'activité physique (0,50; 0,26-0,93) étaient des facteurs de protection. L'allaitement maternel, exclusif ou non, réduisait significativement le risque d'obésité chez les enfants dont les mères n'avaient jamais fumé durant la grossesse. Les FER_p ont indiqué que 24,4 %, 11,5 %, 11,3 % et 6,0 % des cas prévalents d'obésité infantile pourraient être prévenus par l'allaitement maternel exclusif, l'arrêt du tabac durant la grossesse, le sommeil suffisant durant l'enfance et l'évitement d'un poids de naissance élevé, respectivement.

CONCLUSION : De nombreux facteurs de la période périnatale et de l'enfance sont associés à l'obésité chez ces jeunes enfants canadiens. Des stratégies de prévention efficaces ciblant quatre facteurs de risque modifiables chez les mères et les enfants pourraient réduire l'obésité infantile jusqu'à 54 % au Canada.

MOTS CLÉS : obésité infantile; poids de naissance; tabagisme maternel; allaitement; Enquête canadienne sur les mesures de la santé