Birth Weight Curves Tailored to Maternal World Region

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Abstract

Background: Newborns of certain immigrant mothers are smaller at birth than those of domestically born mothers. Contemporary, population-derived percentile curves for these newborns are lacking, as are estimates of their risk of being misclassified as too small or too large using conventional rather than tailored birth weight curves.

Methods: We completed a population-based study of 766 688 singleton live births in Ontario from 2002 to 2007. Smoothed birth weight percentile curves were generated for males and females, categorized by maternal world region of birth: Canada (63.5%), Europe/Western nations (7.6%), Africa/Caribbean (4.9%), Middle East/North Africa (3.4%), Latin America (3.4%), East Asia/Pacific (8.1%), and South Asia (9.2%). We determined the likelihood of misclassifying an infant as small for gestational age (≤ 10th percentile for weight) or as large for gestational age (≥ 90th percentile for weight) on a Canadian-born maternal curve versus one specific to maternal world region of origin.

Results: Significantly lower birth weights were seen at gestation-specific 10th, 50th, and 90th percentiles among term infants born to mothers from each world region, with the exception of Europe/Western nations, compared with those for infants of Canadian-born mothers. For example, for South Asian babies born at 40 weeks' gestation, the absolute difference at the 10th percentile was 198 g (95% CI 183 to 212) for males and 170 g (95% CI 161 to 179) for females. Controlling for maternal age and parity, South Asian males had an odds ratio of 2.60 (95% CI 2.53 to 2.68) of being misclassified as small for gestational age, equivalent to approximately 116 in 1000 newborns; for South Asian females the OR was 2.41 (95% CI 2.34 to 2.48), equivalent to approximately 106 per 1000 newborns. Large for gestational age would be missed in approximately 61 per 1000 male and 57 per 1000 female South Asian newborns if conventional rather than ethnicity-specific birth weight curves were used.

Conclusions: Birth weight curves need to be modified for newborns of immigrant mothers originating from non-European/Western nations.

Key Words: Birth weight, percentiles, curves, small for gestational age, large for gestational age, ethnicity, race, immigrant

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Résumé

Contexte : Les nouveau-nés issus de certaines immigrantes sont plus petits à la naissance que les nouveau-nés issus de mères nées au pays. Nous ne disposons pas de courbes des percentiles contemporaines issues de la population pour ce qui est de ces nouveau-nés et nous ne disposons pas plus d'estimations de leur risque d'être classés, par erreur, comme étant trop petits ou trop grands en raison de l'utilisation de courbes conventionnelles des poids de naissance (plutôt que d'utiliser des courbes de poids de naissance leur étant adaptées).

Méthodes : Nous avons mené une étude en population générale qui portait sur 766 688 grossesses monofœtales ayant mené à une naissance vivante en Ontario, entre 2002 et 2007. Des courbes polies des percentiles en ce qui concerne le poids de naissance ont été générées pour les hommes et les femmes, catégorisées par région de naissance de la mère : Canada (63,5 %), Europe / nations occidentales (7,6 %), Afrique / Caraïbes (4,9 %), Moyen-Orient / Afrique du Nord (3,4 %), Amérique latine (3,4 %), Asie orientale / Pacifique (8,1 %) et Asie méridionale (9,2 %). Nous avons déterminé la probabilité de classer, par erreur, un nouveau-né comme présentant une hypotrophie fœtale (≤ 10e percentile pour ce qui est du poids) ou une hypertrophie fœtale (≥ 90e percentile pour ce qui est du poids) en fonction d'une courbe adaptée aux mères nées au Canada, par comparaison avec l'utilisation d'une courbe adaptée à la région de naissance de la mère à cette fin.

Résultats : Nous avons constaté des poids de naissance considérablement moindres aux 10e, 50e et 90e percentiles propres à l'âge gestationnel chez les enfants nés à terme de mères provenant de chacune des régions mondiales, exception faite de l'Europe / des nations occidentales, par comparaison avec ceux des nouveau-nés issus de mères nées au Canada. Par exemple, dans le cas des enfants d'Asie méridionale nés à 40 semaines de gestation, la différence absolue au 10e percentile était de 198 g (IC à 95 %, 183 - 212) pour les garçons et de 170 g (IC à 95 %, 161 - 179) pour les filles. À la suite de la neutralisation des effets de la parité et de l'âge de la mère, les garçons d'Asie méridionale présentaient un rapport de cotes de 2,60 (IC à 95 %, 2,53 - 2,68) pour ce qui est du risque d'être classés, par erreur, comme présentant une hypotrophie fœtale, ce qui équivalait à environ 116 nouveau-nés sur 1 000; chez les filles d'Asie méridionale, le RC était de 2,41 (IC à 95 %, 2,34 - 2,48), ce qui équivalait à environ 106 nouveau-nés sur 1 000. Pour ce qui est des enfants d'Asie méridionale, l'hypertrophie fœtale passerait inaperçue chez environ 61 garçons sur 1 000 et 57 filles sur 1 000 si l'on avait recours à des courbes de poids de naissance conventionnelles, plutôt qu'à des courbes adaptées à l'ethnicité.

Conclusions : Les courbes de poids de naissance doivent être modifiées pour ce qui est des nouveau-nés issus d'immigrantes ne provenant pas d'Europe / de nations occidentales.

BACKGROUND

Immediately after birth, the weight of an infant is plotted on a birth weight chart to determine if he or she is of appropriate weight for gestational age. This not only provides a baseline measure for future comparison but also has importance in early life. Newborns whose birth weight is below the 10th percentile (i.e., those who are small for gestational age) may be at higher risk of death[1] and short stature, they display lower cognitive ability in mathematics and reading comprehension in early and middle life, and they are less likely to attain higher-income professional or managerial jobs.[2–5] Most investigators recommend that special testing, growth surveillance, and extended newborn hospital stay should be instituted in the postnatal period among SGA-affected infants.[3,6] Labelling an infant as SGA may not only necessitate greater use of health care resources but is also associated with higher parental stress.[7]

At the other end of the spectrum are fetuses and newborns who are large for gestational age (LGA), above the 90th percentile weight for gestational age. They are at higher risk of birth-related trauma, such as shoulder dystocia, requiring resuscitation at birth, and intensive care nursery admission, and their mothers experience a higher rate of emergency Caesarean section and a longer hospital stay.[8,9] LGA infants appear to be at higher risk of obesity at two years of age.[10]

The use of traditional "one size fits all" newborn weight percentile curves[6,11] within the multi-ethnic new immigrant populations of Canada, Australia, the United States, the United Kingdom, and Europe raises several concerns.[12,13] These curves do not take into account the recognized differences in newborn weight between some ethnic groups,[12,13] and the fact that newborns of some ethnic groups (e.g., South and East Asians) deemed to be SGA by conventional curves actually have lower perinatal mortality risks. Second, these out-of-date curves[6,11] do not account for the overall recent increase in newborn weight, or the large new waves of immigration to industrialized nations from non-European countries.[14] Finally, the most cited curves excluded newborns from Ontario, where more than 50% of Canada's immigrants settle.[15,16]

We developed contemporary population-based birth weight percentile charts for male and female live born infants specific to seven maternal world regions of birth, including Canada. Further, we evaluated the absolute number of children of immigrant mothers who were mis-categorized as SGA, or not categorized as LGA, when they were plotted on conventional Canadian rather than world region-specific charts.

METHODS

Data Source and Participants

We completed a population-based study of all singleton live births occurring within Ontario between 2002 and 2007. Live births were identified using birth records provided by Vital Statistics. A birth record requires that two documents are submitted to the Office of the Registrar General, which is part of the Ministry of Government Services of Ontario. The first record is from the attendant/certifier (i.e., physician or midwife) and the other from a parent. The parent record also documents maternal age at delivery, parity, marital status of the parents (yes, no, or unknown), and the birthplace of both the mother and the father of the newborn. The birth attendant records information on the clinical estimate of gestational age, in completed weeks. Although reported errors in the measurement of gestational age in routine birth certificate data in North America have been associated with the use of the menstrual estimate, the clinical estimate may be in error in a small proportion of births.[17,18] We removed records with implausible birth weight for gestational age values based on cut-offs developed on the basis of clinical and statistical criteria.[19]

We categorized each newborn according to the mother's world region of birth, modified from the United Nations classification,[20] as follows: Europe and Western nations, Africa and the Caribbean, Middle East and North Africa, Latin America, East Asia and the Pacific, and South Asia (see online eAppendix 1). Canadian-born mothers served as the reference group. More than one birth may have been included in the study for a given woman.

Data Analysis

Curve generation

Smoothed birth weight percentile curves were derived using non-parametric quantile regression methods.[21,22] When the distribution of the response variable is approximately normal, quantile regression produces virtually similar results to the lambda-mu-sigma method.[22] Curves were fitted using a cubic spline with three degrees of freedom, with knots located at 23, 30, 39, and 40 weeks, and the use of a smoothing algorithm. The position of the knots was identified by stepwise backward regression using the whole dataset, by infant sex, and then applied to each ethnic group separately. As the knots on the curves specific to each maternal world region did not differ substantially from those for the whole dataset, we used the knots obtained for the whole dataset. There were no differences between males and females in the location of the knots. The 3rd, 10th, 25th, 50th, 75th, 90th, and 97th percentiles were calculated from the smoothed curves.

Weight differences

Quantile regression was also used to obtain sex-specific birth weight differences and 95% confidence intervals between the newborns of Canadian-born mothers and those of mothers from other regions. This was done for percentiles 10, 50, and 90, and at 28, 32, 36, and 40 weeks' gestation. Post hoc, we plotted the 50th percentile birth weights of newborns of mothers born in Canada minus other world regions. This analysis omitted data for those born prior to 29 weeks' gestation, to avoid potentially unstable estimates, in lieu of small sample sizes at earlier gestations for some maternal regions.

SGA and LGA misclassification

Using the smoothed curve data, we determined the number and rate of newborns of each maternal world region of origin who were above the 10th percentile SGA thresholds within their own world region-specific birth weight charts but who were, at the same time, below the 10th percentile sex-specific weight cut-points for infants of mothers born in Canada. For LGA, a similar approach was used to identify those above the 90th percentile weight on their ethnicity-specific curve, but below the 90th percentile on the curve for infants of mothers born in Canada. Logistic regression analysis was used to generate crude and adjusted odds ratios and 95% confidence intervals. Odd ratios were adjusted for maternal age (< 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, ≥ 40 years) and parity (1, 2, 3, etc.) in the model, a priori.

Permission to complete the study was obtained from the Research Ethics Board of St. Michael's Hospital, Toronto, Ontario.

RESULTS

There were 772 297 singleton live births documented between the years 2002 and 2007. Of these, 5609 (0.73%) were excluded for one or more of the following reasons: missing infant sex (n = 2), missing or invalid birth weight (n = 593), implausible birth weight for gestational age (n = 748), missing gestational age (n = 609), extreme gestational age (< 23 weeks or > 41 weeks) (n = 4028), or unknown maternal country of birth (n = 842). Thus, 766 688 live born infants were included.

Maternal and newborn characteristics are shown in Table 1. Of note, 36.5% of infants were born to immigrant women, including 9.2% from South Asia and 8.1% from the East Asia/Pacific region. Fathers were reported to originate from the same world region as mothers for 93% of South Asians and 84% of those self-identified as Canadian-born (Table 1). This figure was lower for those originating from European and Western nations (45%) or Latin America (63%) (Table 1). Approximately 93% of infants were born between 37 and 41 weeks' gestation (online eAppendix 1). The overall mean (SD) weight at birth differed by maternal world region of birth (Table 1).

The generated smoothed birth weight percentile charts for singleton newborns, according to maternal world region of birth, are shown in online eAppendices 2a–2n. The corresponding values are found in online eAppendices 1a–1n. For some regions, there were fewer than 10 newborns with a gestational age < 29 weeks.

Table 1. Characteristics of 766 688 live born infants born between 23 and 41 weeks' gestation and their mothers according to maternal world region of birth, 2002 to 2007

	World region of maternal birth (number of deliveries in the period of study)						
Characteristic*	Canadian-born (n = 486 599)	Europe and Western Nations (n = 58 505)	Africa/ Caribbean (n = 37 382)	North Africa/ Middle East (n = 25 650)	Latin America (n = 26 042)	Southeast Asia/ Pacific (n = 61 819)	South Asia (n = 70 691)
Percent of all deliveries	63.5	7.6	4.9	3.4	3.4	8.1	9.2
Maternal							
Mean (SD) age at delivery, years	29.5 (10.3)	31.5 (11.1)	31.0 (13.6)	30.2 (8.1)	29.8 (8.4)	32.3 (13.2)	29.3 (10.1)
Median (IQR) parity	2 (1 to 2)	2 (1 to 2)	2 (1 to 3)	2 (1 to 3)	2 (1 to 3)	2 (1 to 2)	2 (1 to 2)
Marital status							
Married	334 540 (68.8)	48 839 (83.5)	21 956 (58.7)	23 329 (91.0)	19 818 (76.1)	51 825 (83.8)	65 733 (93.0)
Unmarried	72 100 (14.8)	3986 (6.8)	10 881 (29.1)	734 (2.9)	3455 (13.3)	5322 (8.6)	1354 (1.9)
Unknown	79 959 (16.4)	5680 (9.7)	4545 (12.2)	1587 (6.2)	2769 (10.6)	4672 (7.6)	3604 (5.1)
Newborn infant							
Father's world region of birth same as mother's							
Same	408 620 (84.0)	26 455 (45.2)	26 237 (70.2)	21 046 (82.0)	16 430 (63.1)	47 867 (77.4)	66 026 (93.4)
Different	56 978 (11.7)	30 933 (52.9)	7693 (20.6)	4301 (16.8)	8447 (32.4)	11 725 (19.0)	3928 (5.6)
Unknown	21 001 (4.3)	1117 (1.9)	3452 (9.2)	303 (1.2)	1165 (4.5)	2227 (3.6)	737 (1.0)
Female	237 089 (48.7)	28 292 (48.0)	18 426 (49.3)	12 465 (48.6)	12 675 (48.7)	12 465 (48.6)	34 229 (48.4)
Mean (SD) gestational age at delivery, weeks	39.0 (1.7)	39.1 (1.7)	38.8 (2.0)	39.1 (1.6)	38.9 (1.8)	38.8 (1.6)	38.9 (1.7)
Mean (SD) Birth weight, g	3461 (552)	3453 (539)	3297 (581)	3374 (508)	3342 (552)	3280 (491)	3229 (517)

*All data are presented as a number (%) unless otherwise indicated.

IQR: Interquartile range

Significant differences were observed between the newborn weight of infants of Canadian-born mothers and newborn weight at the 10th (Figure 1, Panel A), 50th (Figure 1, Panel B) and 90th (Figure 1, Panel C) percentiles for infants born of mothers from each world region, other than Western nations and Europe. For example, for South Asian males born at 40 weeks' gestation, the absolute difference at the 10th percentile was approximately 200 g compared with the infants of Canadian-born mothers; for females, this difference was 170 g (Figure 1, Panel A). In a post hoc analysis of those born after 28 weeks, the plotted 50th percentile birth weight differences between infants of Canadian-born and foreign-born women were revealing (Figure 2). For South Asian males, this difference increased in a linear manner, from 83 g at 29 weeks to 260 g at 41 weeks' gestation; the association between gestational age and birth weight difference was highly correlated ($r^2 = 0.99$) (Figure 2, Panel A). The slope of this line for South Asian males suggested a 14.1 g increase per week in the birth weight difference. For South Asian females, the corresponding r^2 was 0.98, and the slope of the line approximated a 12.6 g increase per week in the weight difference from infants of Canadian-born mothers (Figure 2, Panel B). Other groups saw varying degrees of weight difference at 29 weeks, and different rates of change thereafter (Figure 2). However, for newborns of mothers originating from European/Western nations, the difference in birth weight was close to zero, and remained so with advancing gestational age.

After controlling for maternal age and parity, South Asian males above the 10th percentile weight on their own world region-specific curves were 2.60 (95% CI 2.53 to 2.68) times more likely to be misclassified as SGA (i.e., below the 10th percentile for weight) using curves for males of Canadian-born women (Table 2). This is equivalent to approximately 116 per 1000 newborn males potentially misclassified as SGA (Table 2). For female newborns of South Asian mothers, the corresponding adjusted odd ratio was 2.41 (95% CI 2.34 to 2.48), or approximately 106 per 1000 newborns mis-categorized as SGA (Table 2). Less pronounced but significant risks of SGA misclassification were observed for all other maternal world regions of origin, with the exception of Europe and Western nations, which showed no higher rate difference for males (0 per 1000) and only 6 per 1000 females (Table 2).

If the birth weight curves for Canadian-born women were used, approximately 61 per 1000 male and 57 per 1000 female South Asian newborns fell below the 90th percentile, when they were otherwise LGA on their own specific birth weight curves (Table 3). These figures were similar for newborns of East Asia/Pacific maternal origin (59 per 1000 and 56 per 1000, respectively), and varied to lesser degrees for other world regions (Table 3).

DISCUSSION

We generated contemporary specific weight percentile curves for live born singleton infants among an ethnically diverse population. Newborns of immigrant mothers weighed up to 250 g less at birth than those of Canadian-born women, with the exception of those originating from European and Western nations. Approximately 1 in 10 infants of South Asian origin were at risk of being categorized as SGA using a Canadian-born curve instead of a world region-specific curve. For newborns of East Asian/Pacific, African/Caribbean, or Latin American maternal origin, the estimate was approximately 1 in 20. In parallel, a significant number of LGA babies born to certain immigrant groups would be missed when plotted on curves for infants of Canadian-born maternal origin.

Our birth weight curves were derived from nearly the entire population of singleton live births in Ontario over a six-year period. Changes in registration charges for live births in Ontario during the 1990s left a small (1%) proportion of births unregistered, especially among poorer young mothers living in an urban area.[23] Overall, this would have had a minimal effect on our dataset, which comprises 99% of all live births, wherein women with the highest apparent rates of SGA newborns—those of South Asian and East Asian origin—also were more likely to be married (Table 1) and to have a university education.[24] Maternal, but not paternal, world region of origin was used, but their concordance was as high as 93% for South Asians, and 84% for East Asians. We could not describe the ethnic composition of the Canadian-born women; however, most Canadian-born mothers in the study period were born 25 to 35 years ago, when the predominant ethnic group was British and European.[25] This is in keeping with our finding of no appreciable birth weight differences between infants born to immigrant mothers from European/Western nations and those of Canadian-born women (Figure 2), which also suggests that a healthy immigrant effect probably does not explain our findings of a lower birth weight in some immigrant groups. Including Canadian-born women with the same ancestry as immigrant women in other world region groups would have, nonetheless, attenuated our risk estimates. We assigned immigrant women to the most ethnically similar regions, in accordance with the United Nations classification.[20] While this optimized our sample size and the generalizability of our findings, we could no longer detect potential differences between individual countries and the impact on newborn weight. For example,

Figure 1A. Absolute difference in birth weight of infants of mothers from six world regions compared with infants of Canadian-born women. Data represent the 10th (Panel A), 50th (Panel B), and 90th (Panel C) percentiles for newborn weight at 28 weeks, 32 weeks, 36 weeks, and 40 weeks of gestation, males and females. Values in parentheses represent the absolute newborn weight for maternal region of birth, percentile, and gestational age

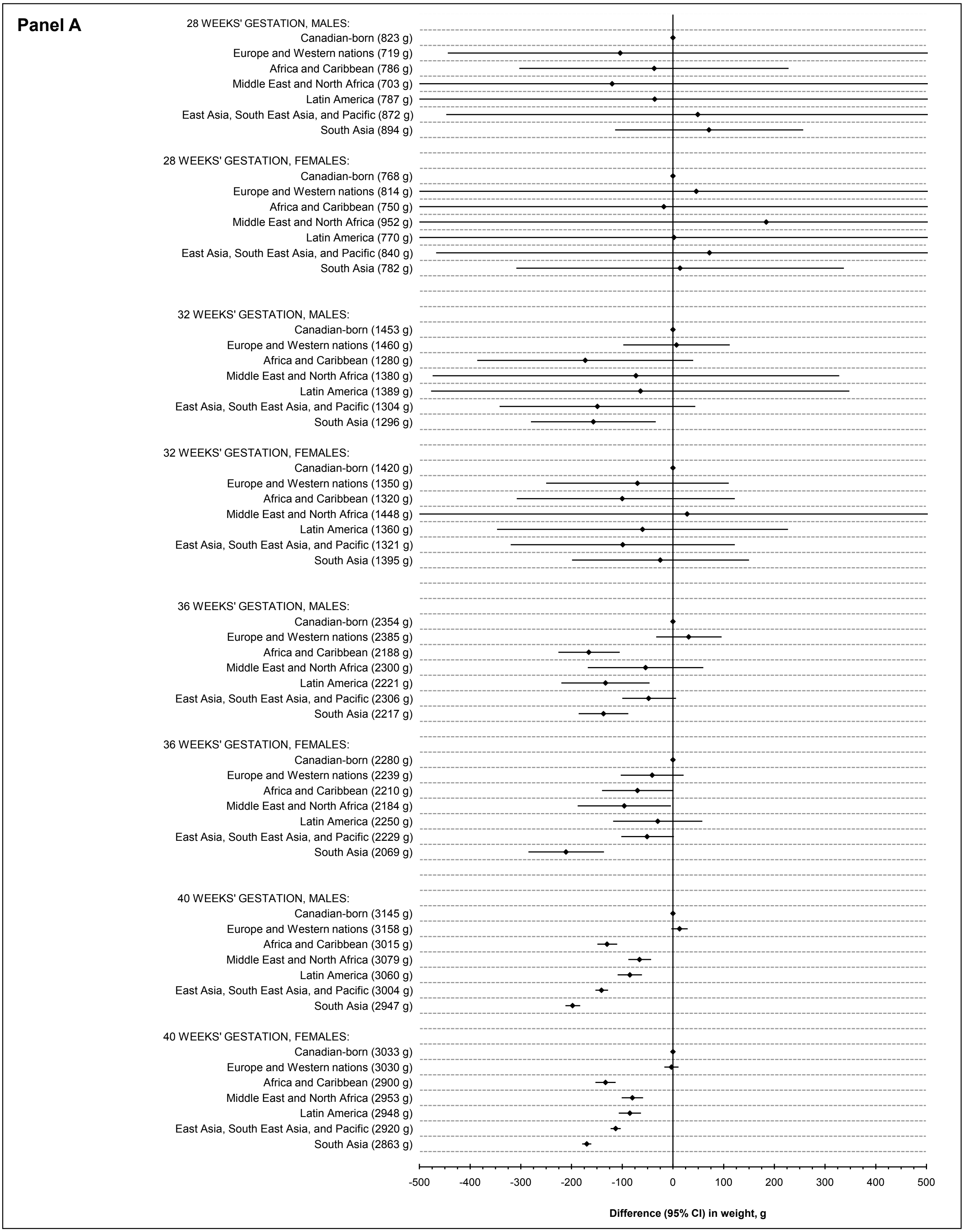

Figure 1B. Absolute difference in birth weight of infants of mothers from six world regions compared with infants of Canadian-born women. Data represent the 10th (Panel A), 50th (Panel B), and 90th (Panel C) percentiles for newborn weight at 28 weeks, 32 weeks, 36 weeks, and 40 weeks of gestation, males and females. Values in parentheses represent the absolute newborn weight for maternal region of birth, percentile, and gestational age

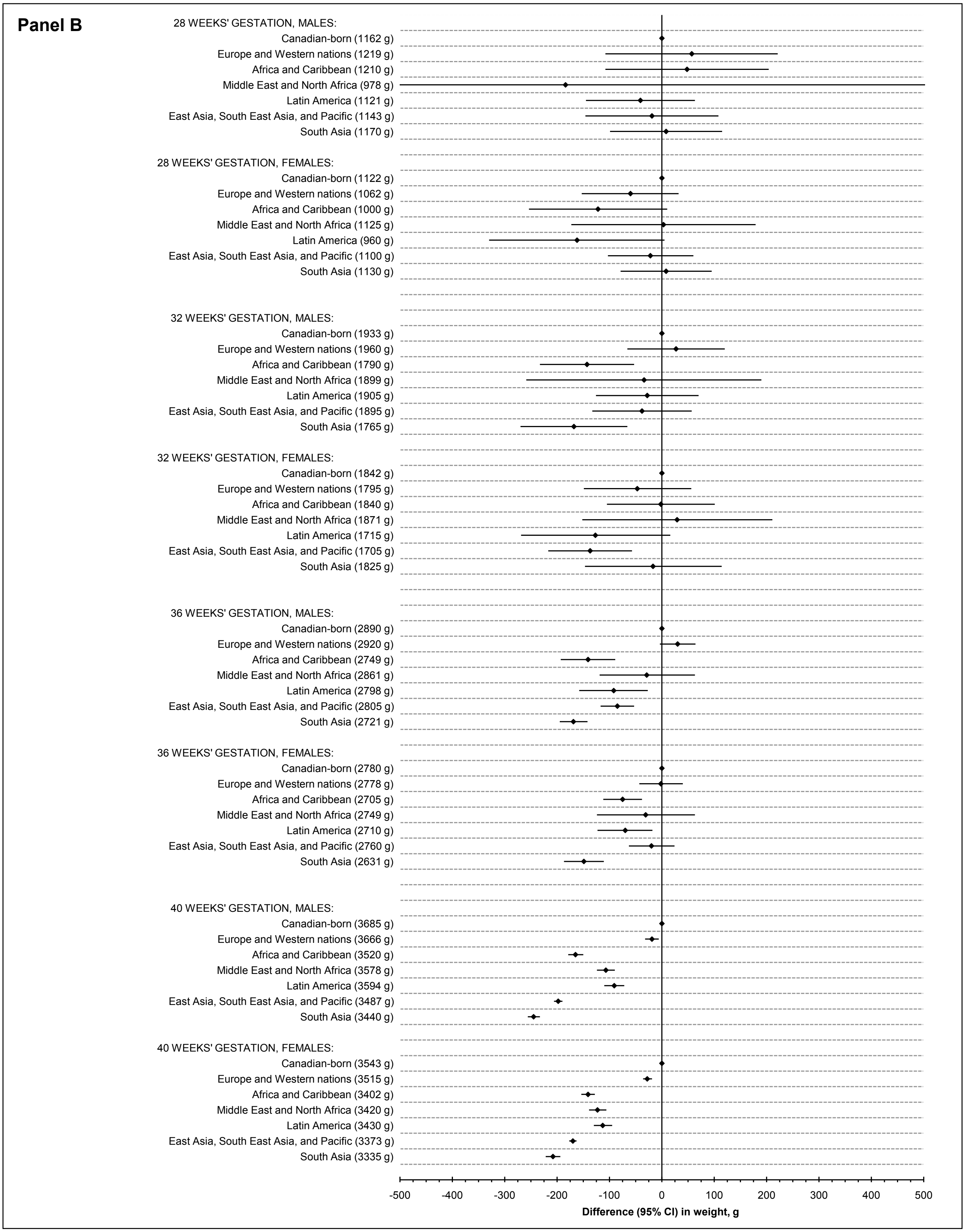

Figure 1C. Absolute difference in birth weight of infants of mothers from six world regions compared with infants of Canadian-born women. Data represent the 10th (Panel A), 50th (Panel B), and 90th (Panel C) percentiles for newborn weight at 28 weeks, 32 weeks, 36 weeks, and 40 weeks of gestation, males and females. Values in parentheses represent the absolute newborn weight for maternal region of birth, percentile, and gestational age

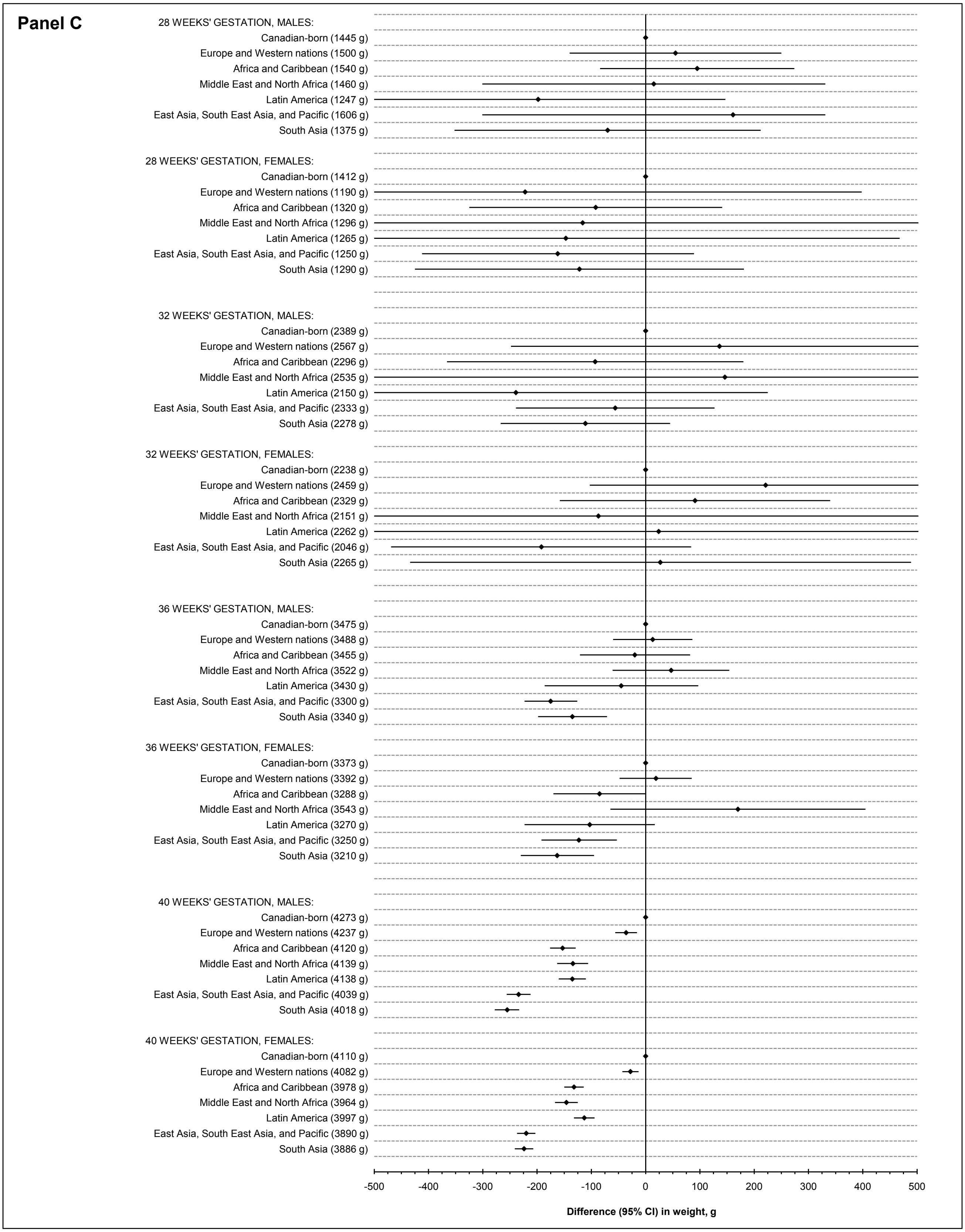

Figure 2. Absolute difference by gestational age in the 50th percentile birth weight values of male (Panel A) and female (Panel B) infants of mothers from six world regions compared with infants of Canadian-born women. Data are limited to births between 29 and 41 weeks' gestation to avoid unstable estimates related to small sample sizes prior to 29 weeks' gestation

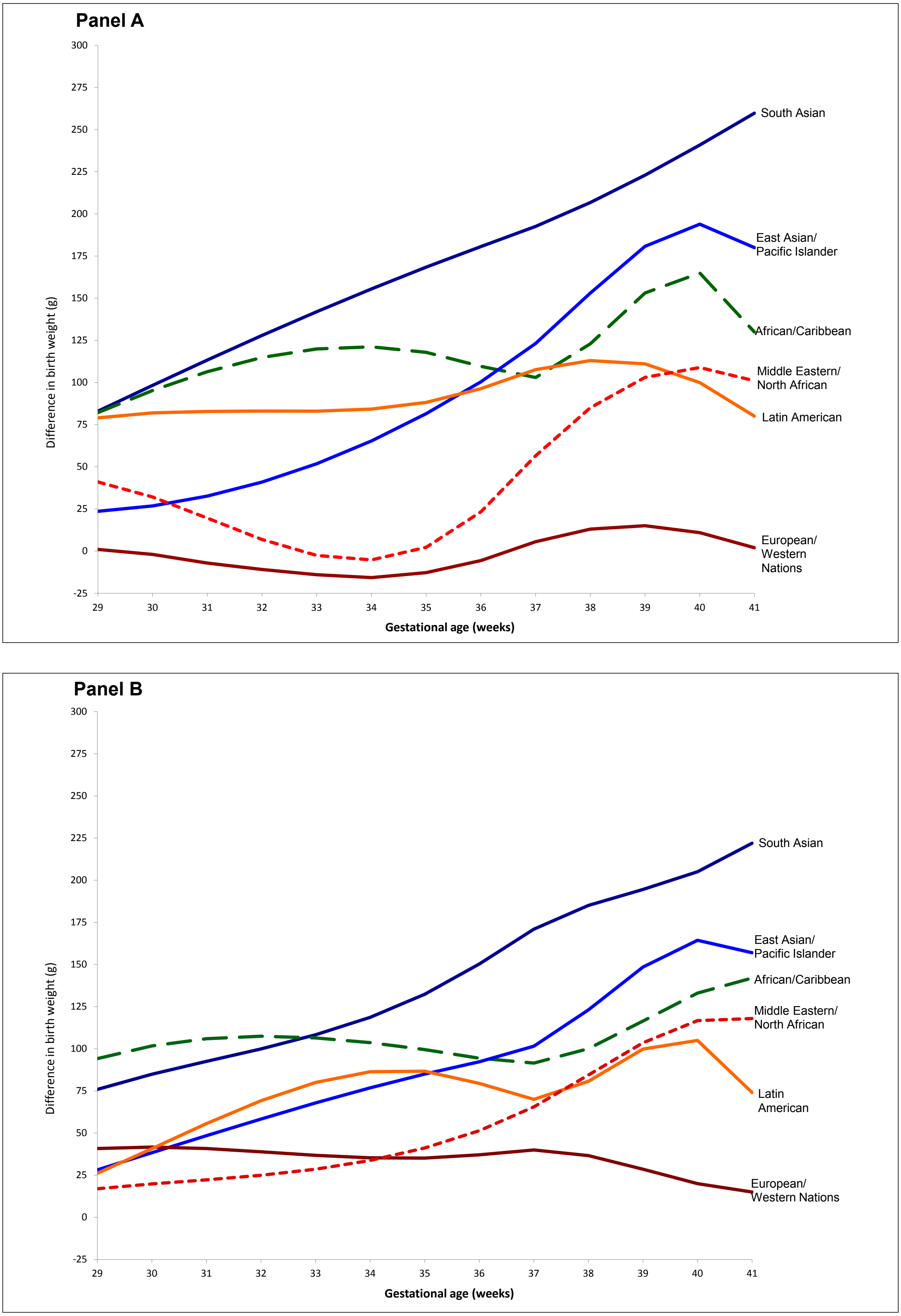

Table 2. Risk that a newborn infant is potentially classified as SGA when plotted on a smoothed weight centiles curve for infants of Canadian-born mothers rather than on a curve specific to its mother's world region of origin

		Maternal world region of birth						
Newborn	Measure	Canadian-born (n = 486 599)	Europe and Western Nations (n = 58 505)	Africa/ Caribbean (n = 37 382)	North Africa/ Middle East (n = 25 650)	Latin America (n = 26 042)	Southeast Asia/ Pacific (n = 61 819)	South Asia (n = 70 691)
Males	n (%)	24 715 (9.9)	2968 (9.8)	3157 (16.7)	1696 (12.9)	1947 (14.6)	5253 (16.4)	7853 (21.5)
	OR (95% CI)	1.00 (ref)	0.99 (0.95 to 1.03)	1.82 (1.75 to 1.89)	1.34 (1.27 to 1.42)	1.55 (1.48 to 1.63)	1.78 (1.72 to 1.84)	2.50 (2.43 to 2.57)
	aOR (95% CI)*	1.00 (ref)	1.04 (0.99 to 1.08)	2.01 (1.93 to 2.10)	1.44 (1.37 to 1.52)	1.63 (1.55 to 1.71)	1.82 (1.76 to 1.88)	2.60 (2.53 to 2.68)
	Newborns potentially misclassified as SGA per 1000 live births, n	—	0	67	30	46	64	116
Females	n (%)	23 559 (9.9)	2957 (10.5)	2898 (15.7)	1726 (13.9)	1811 (14.3)	4594 (15.5)	7036 (20.6)
	OR (95% CI)	1.00 (ref)	1.06 (1.02 to 1.10)	1.69 (1.62 to 1.76)	1.46 (1.38 to 1.54)	1.51 (1.44 to 1.59)	1.66 (1.60 to 1.72)	2.35 (2.28 to 2.42)
	aOR (95% CI)*	1.00 (ref)	1.10 (1.06 to 1.15)	1.84 (1.77 to 1.92)	1.54 (1.46 to 1.63)	1.57 (1.49 to 1.65)	1.69 (1.64 to 1.75)	2.41 (2.34 to 2.48)
	Newborns potentially misclassified as SGA per 1000 live births, n	—	6	58	38	44	56	106

*Adjusted for maternal age groups (< 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, ≥40 years) and parity (1, 2, 3, etc.)

— Not applicable

Table 3. Risk that a newborn infant is potentially missed as being LGA when plotted on a smoothed weight centiles curve for infants of Canadian-born mothers rather than on a curve specific to its mother's world region of origin

		Maternal world region of birth						
Newborn	Measure	Canadian-born (n = 486 599)	Europe and Western Nations (n = 58 505)	Africa/ Caribbean (n = 37 382)	North Africa/ Middle East (n = 25 650)	Latin America (n = 26 042)	Southeast Asia/ Pacific (n = 61 819)	South Asia (n = 70 691)
Males	n (%)	25 031 (10.0)	2698 (8.9)	1216 (6.4)	816 (6.2)	846 (6.3)	1344 (4.2)	1428 (3.9)
	OR (95% CI)	1.00 (ref)	1.14 (1.09 to 1.19)	1.63 (1.53 to 1.73)	1.69 (1.57 to 1.82)	1.65 (1.54 to 1.77)	2.55 (2.42 to 2.70)	2.74 (2.59 to 2.89)
	aOR (95% CI)*	1.00 (ref)	1.20 (1.15 to 1.25)	1.84 (1.73 to 1.95)	1.83 (1.70 to 1.96)	1.78 (1.66 to 1.91)	2.61 (2.47 to 2.76)	2.80 (2.65 to 2.96)
	Newborns potentially missed as LGA per 1000 live births, n	—	11	37	39	38	59	61
Females	n (%)	23,945 (10.1)	1304 (4.4)	1209 (6.6)	738 (5.9)	877 (6.9)	1304 (4.4)	1500 (4.4)
	OR (95% CI)	1.00 (ref)	1.17 (1.12 to 1.22)	1.60 (1.51 to 1.70)	1.79 (1.66 to 1.93)	1.51 (1.41 to 1.62)	2.45 (2.31 to 2.59)	2.45 (2.32 to 2.59)
	aOR (95% CI)*	1.00 (ref)	1.23 (1.18 to 1.28)	1.81 (1.70 to 1.92)	1.92 (1.78 to 2.07)	1.61 (1.50 to 1.73)	2.50 (2.36 to 2.65)	2.49 (2.36 to 2.62)
	Newborns potentially missed as LGA per 1000 live births, n	—	12	36	41	33	56	57

*Adjusted for maternal age groups (< 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, ≥ 40 years) and parity (1, 2, 3, etc.)

— Not applicable

women arriving from European and Western nations could be of White European ancestry or could belong to another ethnic group. In creating these birth weight curves we did not factor in maternal or paternal body size, duration of residence in Canada, or maternal nutrition, smoking, hypertension, or gestational diabetes. However, we recently evaluated 770 875 consecutive deliveries, including 118 849 deliveries among immigrant women, and found that the risk of gestational diabetes was twice as high in women of East Asian ancestry (7.5%) and 3.5 times higher among women from South Asia (10.4%), than in Canadian-born women (3.0%).[26] Thus, since gestational diabetes mellitus tends to cause macrosomia, the fetuses of these two Asian ethnic groups should have been classified as LGA at higher rates, but we actually found the opposite. Finally, we did not exclude live born infants with a congenital or chromosomal anomaly, who together account for approximately 4% of live births in Ontario.[27] However, in a similar population sample, we found no difference in the rate of open neural tube defects between ethnic groups.[28]

The current curves are a major improvement upon those previously published in 2001 by Kramer and colleagues,[11] which included 676 605 Canadian infants live born between 1994 and 1996 but excluded Ontario, Canada's most populous province. Moreover, these authors did not evaluate the ethnic composition of their newborn sample. Our population sample comprised 767 000 recent live births in Ontario, where 55% of all Canadian immigrants settle, making it the most ethnically diverse part of the country.[29] Our estimates of gestational age—a critical element in constructing newborn weight curves—are more accurate than those of Kramer et al.[11] We previously showed that first trimester ultrasonography, the most accurate method for pregnancy dating,[30] was performed in more than 75% of pregnancies within the same population and era as the current study,[31] compared with a rate of only 40% in the era of the curves established by Kramer et al.[11] In fact, Ontario has the highest rate of early prenatal ultrasonography in Canada, with 78% of women having a scan before 18 weeks, and 95% by 20 weeks' gestation.[32] There has been a secular trend in the birth weight of singleton newborns in Canada and the United States, such that contemporary data are best suited to define modern weight standards.[33] Unlike Kramer et al.,[11] we did not find bimodal distributions of birth weight at early gestational ages due to errors in pregnancy dating, and we excluded implausible combinations of birth weight and gestational age using the method of Alexander et al.[19]

We observed no statistically significant difference in birth weight at 28 weeks' gestation between newborns of Canadian-born and those of foreign-born mothers (Figure 1). These imprecise estimates reflect the small number of births before 28 weeks—just 0.33% of the entire sample. It is possible that some of the observed difference between ethnic groups in newborn weight is reflective of more than physiological differences in pregnancy or genetic programming of maximum fetal growth. Controlling for parental birth weight or current body mass index may provide some further insight into the influences of "trait versus state," as would future study of intergenerational differences in birth weight before and after immigration. The evaluation of socioeconomic and health factors in a woman's country of origin might better explain variation in newborn weight than ethnic status alone, as might differences in the time interval between immigration and delivery. Compelling information could also arise from a comparative assessment of placental structure at birth, or by ultrasound in utero,[34] including estimated placental blood flow by using uterine artery Doppler studies. Also, it is prudent to establish whether there are differences in neonatal morbidity and mortality between infants mis-categorized as SGA using conventional curves and those who are truly SGA on their world region-specific curves.

We could not determine the proportion of pregnancies in each maternal world region category affected by placental vascular disease, a predisposing factor for poor fetal growth.[35] However, we know from our prior work that women from South Asia and East Asia experience nearly the same rates of serious preeclampsia (another placenta-mediated condition) as women from industrialized nations,[24] and yet in the present study they consistently had lower birth weight infants. In addition, data from British Columbia have shown that Chinese and South Asian infants have lower perinatal mortality, despite having higher rates of SGA.[13] Hence, it should not be assumed that differences in newborn weight associated with maternal region of birth are due to a pathological process.

Customized birth weight percentiles that consider the influence of maternal characteristics on fetal growth, including maternal height, pre-pregnancy weight, parity, and ethnicity, have been developed.[36–40] However, 93% of mothers in one such study were Anglo-European, and were solely confined to Nottingham in the United Kingdom.[37] Other related studies comprised more ethnically diverse populations, but none were carried out in Canada.[38–41] The utility of customized birth weight percentile curves for predicting perinatal morbidity has been challenged in other studies,[42,43] but those studies did not consider the highly prevalent and broad ethnic groups included in our current study. Interestingly, Mikolajczyk et al. used data from 24 countries that participated in the WHO Global Survey on Maternal and Perinatal Health, comprising 237 025 patients.[44] They showed that adjusting for maternal ethnicity (according to the mother's country of origin) improves the classification of SGA, while consideration of other maternal variables such as height makes little further difference. One assumption in the aforementioned studies is that all ethnic groups have a similar fetal growth pattern (the assumption of "proportionality").[45] Our data suggest that this may not be true: a more detailed post hoc analysis from 29 weeks onward revealed some interesting patterns in 50th percentile weight differences for the various groups (Figure 2). For South Asians, there was a linear increase in weight discrepancies compared with Canadian-born mothers, rising by 14 g per week among males and approximately 13 g per week among females. Among other ethnic groups, with the exception of Latin American and European/Western nations, either a similar or less prominent rise was seen (Figure 2). This suggests that birth weight discrepancies worsen, at least beyond 28 weeks, for the two largest immigrant groups to Canada (and the United States and the United Kingdom), namely, South Asians and East Asian/Pacific Islanders. A comparative analysis of intrauterine fetal growth, using repeated ultrasound measures, might better elucidate whether similar growth trajectories are observed in utero. This is especially important, because infants born preterm are more likely to be growth-restricted, and thus may be of lower weight ex utero than their counterparts at the same gestational age who remain in utero.[45]

Clinicians who provide prenatal and neonatal care for diverse groups of immigrant women and their newborns should consider ethnicity-specific percentile curves,[13,44] like those developed here. Use of these curves will likely prevent mis-identifying an otherwise healthy newborn as "SGA," or missing a fetus/newborn who is truly LGA. If this is done, obstetrical and pediatric resources can be optimally focused on those who warrant further investigation,[46,47] while avoiding unwarranted parental stress.[7] We encourage those who adopt these curves to continue to assess neonatal (and fetal) well-being beyond weight measures alone, using an integrated approach[45] that includes measures of length and head circumference, as well as consideration of rarer prenatal causes of abnormal fetal growth, including chromosomal disorders and intrauterine infections.[48–50]

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