

Intrauterine Growth Standards for Newborns  
of Caucasian, Chinese, and South Asian Descent at Term

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## **CONFLICT OF INTEREST NOTIFICATION PAGE**

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## **ABSTRACT**

### **Background**

Fetal growth restriction is associated with metabolic derangements in the newborn, impaired functioning in early childhood, and chronic diseases in adulthood. Currently, standards for birthweight, length, and head circumference stratified by both sex and ethnicity are not available. Differences in fetal growth between ethnic groups may result in the misclassification of normal but constitutionally small or large babies. We developed and compared intrauterine growth charts based on precise morphometric measurements of newborns whose parents were both of Caucasian, Chinese, or South Asian ethnicity.

### **Methods**

Weight, length and head circumference were measured on 2695 babies born to healthy non-smoking mothers in British Columbia whose gestational age between 37 and 41 completed weeks was confirmed by ultrasound prior to 20 weeks gestation. Weight was measured on a digital scale, length by stadiometer, and head circumference by firm plastic tape measures. Means and 95% confidence intervals of morphometric measurements were compared among newborns grouped by ethnicity and sex. Smoothed graphs were constructed for visual interpretation.

## **Results**

Newborns of Chinese descent were on average, lighter than Caucasian babies and shorter than South Asian babies. South Asian babies were also lighter than Caucasian babies but similar in length. These differences were on average larger in magnitude than those between sexes at a given gestational age. Mean head circumference of Chinese and South Asian babies were less than those of Caucasians but these differences were not statistically significantly different except between Caucasian and Chinese babies at forty weeks gestation.

## **Conclusions**

Important differences among weight, length, and head circumferences are reported among babies of different ethnicities. Use of sex and ethnicity-specific growth charts may prevent the misclassification of newborns at birth as growth-restricted or large for gestational age.

**Key Words:** Ethnicity, growth, intrauterine, measurement, morphometry, sex

## INTRODUCTION

Evaluation of growth parameters at birth is undertaken to identify the newborn whose growth is judged to be abnormal. Newborns who have suffered intrauterine growth restriction in utero have been exposed to adverse conditions which may have implications for the immediate neonatal period and on through childhood, adolescence and adulthood. Severely growth restricted newborns are particularly susceptible to neonatal hypothermia, hypoglycemia, polycythemia, blood hyperviscosity, and infection.(1-3) At the 5<sup>th</sup> birth weight centile for gestational age, perinatal mortality is 15/1000 and rises to 150/1000 at the 1<sup>st</sup> centile.(4) Mortality and morbidity are still elevated at the 10<sup>th</sup> centile compared with appropriate for gestational age infants. Excess mortality is associated in part to an increased risk (30-60%) of minor and major anomalies.(2)

Fetal growth restriction has been shown to have a deleterious effect on cognitive functioning in later childhood, independent of genetic or major organ system malformations.(5, 6) Decreased insulin sensitivity in the pre-teen years has been associated with fetal growth restriction.(7) The growing weight of evidence linking reduced fetal growth with adult-onset diabetes and coronary heart disease (adult metabolic syndrome)(8) underlines the importance of the intrauterine environment as a determinant of adult health.

Variability in fetal growth parameters at birth is known to be associated with sex of the baby, gestational age at birth, and multiplicity.(9) Controversy exists as to which growth curves are most appropriate, but there is a growing consensus that standards must relate to a specific geographic area and must include race/ethnicity in addition to other parameters.(2) Historically, studies reporting differences in morphometric measures at birth according to race/ethnicity have compared between rather than within countries.(10, 11) In contrast, a Canadian study compared

infants of Caucasian and immigrant Chinese infants born in Montreal between 1978-1990.(12) Use of an obstetric and neonatal database allowed the investigators to compile “risk free” cohorts for comparison. Racial status was derived from the mother’s maiden name. The study reported mean birthweight-for-gestational-age increments of 180 g or more for Caucasian vs. Chinese infants but did not report on length or head circumference. Comparison of length and head circumference allow for distinction between symmetrical and asymmetrical growth, an important measure of the severity and duration of restricted growth in utero.(2)

At present, there are no standards for intrauterine growth measured at birth which are specific to ethnic groups and which include length and head circumference in addition to weight. In Canada the second largest ethnic group (after European origin) is Chinese, with over just over one million persons self identifying on this group.(13) The fourth largest subgroup, after aboriginal persons, is South Asian, at 700,000. In the current study, we developed ethnicity, sex, and gestational-age specific charts of birthweight, length, and head circumference for newborns of Caucasian, Chinese, and South Asian descent.

## **METHODS**

### **Setting**

BC Women’s Hospital, the setting of the current study, serves as a primary obstetrical care facility for residents of Vancouver and the surrounding Lower Mainland area in British Columbia. Forty percent of women delivering at BC Women’s Hospital are of East Asian (China, Taiwan, Hong Kong, Vietnam, Laos, Cambodia) descent and 10% are of South Asian (India, Pakistan) descent. During the study period, 2000-2003, routine screening for congenital dislocation of the hip was undertaken by orthopedic surgical residents at BC Women’s Hospital.

The thrice-weekly assembly of all newborns in the nursery for this purpose afforded us an opportunity to undertake precise measurements of length and head circumference.

### **Sample**

We restricted our sample to newborns of healthy mothers in order to develop standards for normal intrauterine growth. Newborns were eligible if their mothers had expected dates of confinement (EDC) between 36 and 41 completed weeks of pregnancy confirmed by ultrasound measurement of fetal biparietal diameters or crown rump length obtained before 20 weeks of pregnancy. We limited our inclusion criteria to 36-41 weeks of gestation because of our limited access to newborns of younger gestational age and our belief that babies born at preterm gestations may have been exposed to in utero conditions affecting growth and could not therefore be reliably assumed to follow a “normal” growth standard.(14)

Parents of study subjects were a) both Caucasian; b) both East Asian; or c) both South Asian (IndoCanadian). Race/ethnicity was determined by a perusal of a) the prenatal record in which ethnicity is recorded; and b) a socio-demographic form completed by labor/delivery nurses which includes a field for race/ethnicity. If these two sources of information were not in agreement, the baby was not included in the study. Babies born to First Nations (aboriginal parents) were not enrolled as they constituted only 1% of the population giving birth at BC Women’s Hospital, and would therefore not constitute a sample large enough to develop precise estimates of morphometry.

Babies were excluded if their mothers’ pregnancies were complicated by any conditions which could potentially alter fetal growth, including pre-existing or gestational insulin-dependent diabetes, pre-eclampsia, fetal anomalies, multiple gestation or known or suspected syndromes.

Babies born to mothers who disclosed use of substances during pregnancy as reported on the prenatal record (tobacco, alcohol, and other illicit drugs) were not included.

### **Gestational Age**

Gestational age at birth for each newborn was derived from the expected date of confinement (EDC), calculated on the basis of both early ultrasound and the date of the last menstrual period (LMP). Obstetrical wheels use Nagle's rule to align dates of LMP with the corresponding EDC. We used a large scale obstetrical wheel to estimate EDC from LMP because comparisons of palm-sized wheels have revealed differences in calibration of weekly intervals. (15) To determine EDC based on ultrasound evaluations, original ultrasound reports were reviewed for all subjects and EDCs re-calculated. In the event of disagreement between the two methods, the initial estimate of gestational age at birth by LMP was adjusted to that derived by ultrasound if the discrepancy was  $\geq 6$  days at 7 - 12 weeks,  $\geq 7$  days at 13 - 14 weeks,  $\geq 8$  days at 15 - 20 weeks, and  $\geq 14$  days at 20 - 24 weeks gestation, according to the method of Synnes et al. (1994).(16)

Morphometric measurements were completed on a total of 2595 eligible newborns. After recalculating gestational age at birth based on original ultrasound reports and LMP, 28.5% of gestational ages were changed ( $n = 765$ ). Changes ranged from one to three weeks. Reasons for changing gestational age included: errors in calculation of expected date of confinement (EDC) based on last menstrual period (8.2%,  $n = 221$ ) when use of LMP was appropriate; EDC not adjusted according to ultrasound when it should have been according to Synnes et al. (1999) (6.3%,  $n = 166$ ); EDC calculated incorrectly from ultrasound report (2.1%,  $n = 57$ ); EDC corrected according to ultrasound inappropriately according to Synnes et al. (6.0%,  $n = 161$ ); and



if the discrepancy between EDC calculated in the infant's chart vs. that calculated by the authors could not be determined from the information given (5.9%,  $n = 160$ ).

### **Morphometric Measurement**

Measurement of growth parameters was completed within 48 hours of birth. Length was measured using a stadiometer, which consisted of a hard plastic platform with a vertical headboard against which the crown of the baby's head was placed. With diapers loosened to permit free movement of the legs, the legs were held flat (knees down) and a movable foot board was pressed gently against the balls of the feet, which were held in a position perpendicular to the legs. The measurement of length was then recorded from the crown to the soles of the feet using the centimeter scale on the stadiometer. The head circumference was measured using a firm heavy-weight plastic tape. Paper tapes were considered to be inadequate because of observed variability in printed measurement intervals and metal tape measures were not used in order to avoid lacerations. The plastic tape was checked throughout the study against an identical tape, which was not used for measurement, to ensure that stretching of the tape had not taken place. All measurements were made by an experienced pediatric nurse assisted by a medical student. Inter-rater reliability between the nurse and student was within 0.1 cm for head circumference and length. Birthweight was documented in the birth record immediately after birth when the baby had been dried but before breastfeeding. Two digital scales in the delivery suite were calibrated using a standard weight to ensure accuracy and comparability.

### **Statistical Analysis**

Means and 95% confidence intervals were graphed to compare differences between newborns grouped first by ethnicity and then by sex. Plots of crude data suggested moderate non-linearity and therefore smoothing (using *lowess* smoother in Splus) of sample means and

standard deviations was undertaken using a locally-weighted least square regression.(17, 18) We present data using means and standard deviations to reflect biological variability as opposed to percentiles, which are essentially a mathematical cut-off.

## **Sponsorship**

Funding for this study was provided by the British Columbia Children's Hospital Foundation after peer review. The Foundation did not contribute to the study design, collection, analysis or interpretation of data, or composition of this manuscript. Ethical approval was granted by the University of British Columbia Clinical Ethics Board and the BC Women's Hospital Research Review Committee.

## **RESULTS**

Morphometric measurements were completed on 2595 newborns; 1195 born to Caucasian parents; 975 born to Chinese parents; and 525 born to South Asian parents. (Table 1). The mean differences in birthweight among babies of differing ethnicities was similar to, or greater than, mean differences between sexes. For example, at 40 weeks gestation, the mean difference between birthweights for Caucasian vs. Chinese babies was approximately 220g (Figure 1) whereas the mean difference between Caucasian girls and boys at 40 weeks was 48g (Table 2). At gestational ages of 37-41 completed weeks, babies of Chinese and South Asian descent had statistically significantly lower mean birthweights than Caucasian babies but were not different from each other. (Figure 1)

A different picture emerged when comparing birth length. Caucasian babies were significantly longer than Chinese babies. South Asian babies' lengths were on average between those of Caucasian and Chinese babies and not significantly different from either. (Figure 2)

Mean differences between Caucasian and Chinese babies at a given gestational age were approximately 1.0 cm. This difference contrasts with a mean difference in length of 0.6 cm between Caucasian girls and boys at 40 weeks gestation. (Table 2).

More variation existed when comparing head circumference according to ethnicity. Head circumferences for Chinese and South Asian babies were similar at the same gestation, with both tending to be approximately 0.5 cm smaller than Caucasian babies (Figure 3). However, 95% confidence intervals overlapped at all gestational ages except for the Caucasian vs. Chinese babies at 40 weeks. Differences in head circumference by sex were larger on average, at about 0.7 cm (Table 2). Smoothed curves for weight, length, and head circumference by sex and ethnicity are presented in Figures 4-9.

## **DISCUSSION**

We report, for the first time, sex and ethnicity-specific parameters for weight, length, and head circumference for infants born at 37-41 completed weeks of pregnancy. Standards assume optimal growth and can be used to detect clinically relevant deviations from normal, which carry risk for morbid consequences. Standards are to be distinguished from population-based references, which include all infants with morbidities and must be interpreted more broadly. Our model for this study, the first Canadian "gold standard" developed by Usher and McLean in 1969, restricted their sample to infants of mothers experiencing healthy pregnancies and utilized meticulous measurement techniques. (19) Our charts differ from references currently in use(20) in that they are derived from a healthy population, that is infants whose mothers had experienced healthy pregnancies and who did not use alcohol, tobacco, or illicit drugs. In addition, we used precise measurement techniques, including recalculation of EDC from ultrasonography. Morphometric measurements at birth conducted without stadiometers or standardized techniques,

as documented routinely in health records, have been shown to have a 5% relative error in measurement of infant length.(21)

Our data indicate that variation in growth by ethnicity is as great as that measured on the basis of sex. Infants who are not compared to standards derived from their specific ethnic group may be misclassified as small or large for gestational age at birth. Similar to our study, a British study of three hospitals with a geographically defined catchment area excluded babies whose mothers with known maternal/fetal morbidities and without confirmation of EDC by early (24 week) ultrasound.(22) From the years 1986-1991 mean birthweights for newborns of non-smoking English/European, Afro-Caribbean, and Indian/Pakistani mothers were presented for both sexes combined. The authors did not report on how the racial groups were defined. Mean birthweights at 40 weeks for South Asian babies (3334g) were less than our values for boys (3452g) or girls (3376 g). This difference may reflect secular increases in birthweight.(23, 24) A study comparing birthweights of babies born to Chinese vs. Caucasian parents in 1980-87 derived from birth records in the US reported mean differences of 200g at 40-41 weeks gestation, a relative difference of 6% of the total birth weight. This study combined data for both boys and girls. (25) Another study collecting data from the same time period in the US reported differences in the range of 5-6% among term Chinese newborns compared to Caucasians.(26)

Reasons for differing intrauterine growth velocities according to race/ethnicity among apparently healthy populations are relatively unexplored. Wen and colleagues in Canada reported more rapid fetal growth early in the third trimester but slower growth near and after term among Chinese vs. Caucasian infants.(12) Lower mean birth weights were due to differences in fetal growth rate rather than gestational duration after adjustment for maternal determinants of fetal growth. Our data support this explanation. Careful examination of Figure 1

indicates a flatter slope for increase in weight by gestational week for Chinese vs. Canadian babies. The ponderal index ( $[\text{weight (g)} / \text{length}^3 \text{ (cm)}] \times 100$ ) is a measure of growth restriction which identifies “wasting” or “thin” babies. The mean ponderal index for Caucasian ( $2.84 \pm 0.33$ ) vs. Chinese babies ( $2.82 \pm 0.40$ )  $\text{g/cm}^3$  was not different in our study, ( $p = 0.50$ ), adjusted for gestational age. In contrast, the ponderal index for Caucasian vs. South Asian babies in our data,  $2.68 \pm 0.46$ , was significantly different ( $p < .001$ ), adjusted for gestational age. This suggests that growth of South Asian babies in our setting may be restricted by factors not accounted for in our sampling, for example, nutritional status of the mother. Fetal growth among South Asian women in Canada has not been studied in detail but may be subject to dietary or other intervention.

Compared to a recently published Canadian sex but not ethnicity- specific reference for birth weight for gestational age based on birth certificate data, mean birthweights in our distribution at 40 weeks gestation are 74 g larger on average for Caucasian boys, 161 g larger for Caucasian girls and 100 g smaller for babies of Chinese and South Asian descent, reflecting the changes in the directions expected for each ethnic group.(20) Another British Columbia reference for birthweights 1981 through 1990 for babies of European, Chinese, and South Asian origin, reports comparable or slightly smaller values compared to ours, again likely reflecting secular trends, but these are reported for both sexes combined and thus have limited utility.(27)

Our study is limited by our inability to report growth standards for babies of less than 37 weeks gestation. Investigators extending our work should be encouraged to identify a population of newborns for whom prematurity appears to be unrelated to factors which affect fetal growth. We are also limited by small numbers in categories formed by stratification on sex and ethnicity. It must be understood, however, that the homogeneity of our sample combined with accurate

measurement has improved precision. The dispersion around the mean in our categories of birthweight at two standard deviations is similar to that at the 5<sup>th</sup> and 95<sup>th</sup> percentiles in the new Canadian distribution based on all live births.(20)

Our charts may be used by clinicians to diagnose individual newborns as small or large for gestational age at birth and to determine the need for close observation and follow-up. Misclassification of a healthy, but constitutionally small newborn as growth restricted may invoke unnecessary monitoring, including phlebotomy for repeated measurement of serum glucose and other parameters. Anxiety on the part of the parents as well as over-utilization of scarce nursing and laboratory resources are additional adverse sequelae associated with identification of “false positives.” Small babies who are inappropriately classified as normally grown, “false negatives”, on the other hand, may be overlooked. In addition, intrauterine growth restriction is a marker for maternal disease or risk behaviours such as hypertension, both pre-existing and gestational, viral infections, use of tobacco and/or illicit drugs, and poor nutritional status. Failure to diagnose growth restricted infants may be therefore be a missed opportunity to intervene on behalf of the mother and future pregnancies.(2) Failure to identify undergrown newborns may also preclude opportunities to identify and intervene early with children at risk for disability.

Our data should not be interpreted as “explaining” the determinants of restricted fetal growth as race/ethnicity may be proxy measures of diet, activity, stress, education, socio-economic status, access to health care and other factors.(28, 29) One group has reported interactions between race and maternal variables such as education, marital status, and access to prenatal care when studying determinants of gestational-age specific birthweight.(26) Ongoing efforts to elucidate the determinants of fetal growth among racial/ethnic groups should include

evaluation of these parameters. The current study provides contemporary charts to assist the clinician in accurately classifying babies of Caucasian, Chinese or South Asian descent at term gestations as growth restricted or large for gestational age.

Table 1. Distribution of Study Subjects by Gestational Age at Birth and Ethnicity

	<u>Gestational Age At Birth In Completed Weeks</u>					
Parents	37	38	39	40	41	Total
Both Caucasian	100	240	282	343	230	1195
Both Chinese	95	241	295	228	116	975
Both Indocanadian	43	106	136	155	85	525
Total	238	587	713	926	431	2695



Table 2. Means and standard deviations for Birthweight, Length and Head Circumference by Sex, Gestational Age at Birth and Ethnicity

<u>Boys</u>												
Caucasian					Chinese				South Asian			
Weeks	n	Weight	Length	HC*	n	Weight	Length	HC	n	Weight	Length	HC
37	52	3336.4 $\pm$ 434.3	49.4 $\pm$ 2.0	34.5 $\pm$ 1.1	46	3119 $\pm$ 361.9	48.3 $\pm$ 1.6	33.9 $\pm$ 1.2	26	3060 $\pm$ 346.1	48.7 $\pm$ 3.9	34.6 $\pm$ 3.0
38	121	3359.4 $\pm$ 416.3	49.4 $\pm$ 1.7	34.7 $\pm$ 1.1	133	3209.5 $\pm$ 356.5	48.4 $\pm$ 2.0	34.3 $\pm$ 1.7	56	3201.8 $\pm$ 397.8	50.2 $\pm$ 2.2	34.3 $\pm$ 1.4
39	124	3586.0 $\pm$ 460.3	50.47 $\pm$ 1.9	35.2 $\pm$ 1.1	141	3359.0 $\pm$ 390.4	49.4 $\pm$ 2.0	34.8 $\pm$ 1.6	70	3361.2 $\pm$ 383.5	50.2 $\pm$ 1.7	34.6 $\pm$ 1.1
40	171	3687.6 $\pm$ 410.5	50.8 $\pm$ 1.7	35.4 $\pm$ 1.0	101	3500.4 $\pm$ 343.5	50.1 $\pm$ 1.6	34.9 $\pm$ 1.0	71	3452.5 $\pm$ 399.1	50.4 $\pm$ 2.5	35.2 $\pm$ 2.3
41	124	3877.1 $\pm$ 384.4	51.4 $\pm$ 2.2	35.9 $\pm$ 1.6	60	3724.1 $\pm$ 522.3	50.9 $\pm$ 2.1	35.6 $\pm$ 1.1	52	3674.7 $\pm$ 363.1	51.4 $\pm$ 1.5	35.3 $\pm$ 1.0
<u>Girls</u>												
37	48	3050.7 $\pm$ 414.1	47.4 $\pm$ 2.5	33.8 $\pm$ 2.3	49	3048.4 $\pm$ 402.9	47.6 $\pm$ 1.7	33.4 $\pm$ 1.2	17	2956.8 $\pm$ 436.3	48.2 $\pm$ 2.2	33.0 $\pm$ 1.2
38	118	3293.5 $\pm$ 423.3	48.6 $\pm$ 1.8	34.0 $\pm$ 1.1	105	3190.2 $\pm$ 377.1	48.2 $\pm$ 1.6	33.8 $\pm$ 1.0	49	3118.4 $\pm$ 371.4	48.8 $\pm$ 1.8	33.7 $\pm$ 1.2
39	154	3455.8 $\pm$ 434.0	49.4 $\pm$ 1.7	34.3 $\pm$ 1.1	151	3271.0 $\pm$ 424.1	48.7 $\pm$ 1.7	34.1 $\pm$ 1.1	64	3311.7 $\pm$ 458.5	49.5 $\pm$ 1.9	34.2 $\pm$ 1.2
40	167	3639.47 $\pm$ 458.2	50.2 $\pm$ 1.8	34.7 $\pm$ 1.1	126	3373.3 $\pm$ 362.3	49.2 $\pm$ 2.2	34.3 $\pm$ 1.5	83	3376.1 $\pm$ 389.4	50.0 $\pm$ 2.6	34.5 $\pm$ 2.0
41	104	3696.8 $\pm$ 448.0	50.5 $\pm$ 1.6	35.0 $\pm$ 1.1	56	3451.0 $\pm$ 344.5	49.4 $\pm$ 2.7	34.7 $\pm$ 2.0	33	3411.4 $\pm$ 401.6	50.6 $\pm$ 1.6	34.7 $\pm$ 1.1

\* Head circumference

Figure 1. Birthweight Distribution By Gestational Age and Ethnicity

Figure 2. Birth Length Distribution By Gestational Age and Ethnicity

Figure 3. Head Circumference at Birth by Gestational Age and Ethnicity

Figure 4. Caucasian Girls

Figure 5. Caucasian Boys

Figure 6. Chinese Girls

Figure 7. Chinese Boys



Figure 8. South Asian Girls

Figure 9. South Asian Boys

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