



# Regional Gestational Age and Gender-Specific Birth Weight Reference Charts and its Comparison with Existing National and International Standards: A Cross-Sectional Study

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## Abstract

**Background** Growth potential is influenced by race, ethnicity, and environmental factors and assessment of growth using standardized charts is important for quality improvement initiatives in health care delivery and public health interventions of any nation.

**Objective** This article aims to develop regional gestational age and gender-specific reference for birth weight and to compare it with published literature.

**Methodology** This study was conducted in a teaching hospital in Puducherry, India and included 2,507 singleton babies. Babies with major congenital anomalies, maternal chronic illness, and nonavailability of first trimester dating scan were excluded. Detailed anthropometric measurement was done for these babies by single investigator as per established norms, their gestation- and sex-specific mean weight and weight percentiles were calculated and compared with existing data.

**Results** Both 10th and 90th percentiles were lower across all gestational ages compared with existing international standards. The proportion of late preterm and term small for gestational age (SGA) babies was 23% using Fenton-2013 reference chart, 14% using Intergrowth-21 chart, and 10% using the current study data ( $p < 0.0001$ ). The proportion of large for gestational age (LGA) babies was 8.5%, using study data. Mean birth weight of male and female term babies born to primiparae were significantly higher compared with multiparae ( $p = 0.03$  and  $0.02$ , respectively).

**Conclusion** Indian babies may be overdiagnosed as SGA or underdiagnosed as LGA based on existing western standards in which our patient population is underrepresented. There is a need for gestational age-, gender-, and parity-specific regional growth charts for better characterization of anthropometric measures of Indian babies.

## Keywords

- ▶ newborn
- ▶ birth weight percentile
- ▶ small for gestational age
- ▶ large for gestational age

## Introduction

Newborn anthropometry by gestational age and sex have been studied by several authors throughout the world start-

ing from Lubchenco et al in 1963, who were the first to introduce the intrauterine weight-based growth chart for various gestational age from the viable period. The inherent disadvantages of Lubchenco's chart, noticed over time, led to

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the development of Millennium cohort in 2000, Fenton Preterm Growth Chart in 2003, World Health Organization Multicentre Growth Reference Study (WHO MGRS) in 2006, Fenton 2013 charts (meta-analysis of seven cross-sectional studies including WHO study) to merge preterm growth charts with new WHO growth standards, and finally the International Growth standards by INTERGROWTH-21<sup>st</sup> Consortium.<sup>1,2</sup> As the growth potential of the fetus is influenced by race, ethnicity, socioeconomic status, environmental factors, gestational factors, maternal nutrition, and weight gain during pregnancy apart from newborn's sex, any noted abnormal deviation of measurement in the local population from international parameters will offer a definite insight for further exploration of the role of predisposing factors and etiological factors that are likely to be operational. Available estimates for the prevalence and mortality of small-for-gestational-age babies show that these assessments are a major focus for quality improvement initiatives in health care delivery and public health interventions of any nation. The objective of this study is to develop a regional gestation and gender-specific reference chart for birth weight of newborn babies. The secondary objective was to determine the proportion of low birth weight (LBW) babies and to study the factors associated with LBW.

## Methodology

This prospective cross-sectional study was conducted in a medical college hospital which serves pregnant mothers from a union territory and two adjacent districts of the neighboring state in southern part of India. All inborn singleton babies born between 28 and 42 weeks of gestational age were included in the study by convenient sampling method, between November 2014 and May 2016 after obtaining informed consent from the mother, following approval by our Institutional Human Ethics Committee. Babies born to mothers for whom dating scan was not done and mothers with known medical illness were excluded from the study. Babies with major congenital anomalies were also excluded from the study. The completed gestational age in weeks as suggested by the antenatal ultrasonography (1st trimester dating scan) was noted for all deliveries. Babies born before 37 completed weeks of gestation were considered as preterm and those born between 34<sup>0/7</sup> and 36<sup>6/7</sup> weeks were termed as late preterm babies as per standard definition. Basic demographic data like maternal height, socioeconomic status (based on Kuppuswamy's Socioeconomic Status Scale<sup>3</sup>), birth order, presence of pregnancy-induced hypertension (PIH), gestational diabetes mellitus (GDM), oligohydramnios, hypothyroidism, and anemia were noted. Detailed anthropometric measurements of the babies were obtained by a single observer, adequately trained in anthropometric measurements. Weight was measured by an electronic weighing scale with an accuracy to the nearest 10 g. Head circumference was measured using a nonstretchable tape with an accuracy to the nearest 0.1 cm. Length was measured using an infantometer with an accuracy to the nearest 0.5 cm. Babies born with birth

weight less than 2.5, 1.5, and 1 kg were defined as LBW, very LBW (VLBW), and extremely LBW (ELBW) babies, respectively, as per standard definition.

## Statistical Methods

Descriptive data check was done, and clear-cut outliers were identified by Tukey's methodology and excluded. Skewed data for each gestational age were transformed to normal distribution by Box-Cox method. Normality of distribution was checked by Q-Q plots and Kolmogorov-Smirnov test. Proportion of preterm births, LBW, VLBW, and ELBW babies were calculated and compared with the existing national data. Mean and standard error of mean with 95% confidence interval (CI), standard deviation, and percentiles were calculated for weight for each gestational age. Generated data was compared with data from an Indian study from Christian Medical College (CMC), Vellore, India by Kumar et al<sup>4</sup> using two-sample z test. Proportion of small for gestational age (SGA) and large for gestational age (LGA) babies using our study percentile was compared with Fenton 2013 and WHO Intergrowth-21 (IG-21) standards using Pearson's chi-square test. All statistical analysis was done using Statistical Package for the Social Studies, version 21.

## Results

A total of 2,507 babies were enrolled in the study after obtaining written informed consent. Of these babies, 1,304 (52%) were male and 1,203 (48%) were female babies. Of the total, 14 (0.6%) babies were very preterm (28–31<sup>6/7</sup> weeks), 14 (0.6%) were moderate preterm (32–33<sup>6/7</sup> weeks), and 122 (4.9%) were late preterm (34–36<sup>6/7</sup> weeks). First-order births constituted 57% ( $n = 1,439$ ) of the study population. With respect to socioeconomic status, majority belonged to middle class (59%) and upper lower class (35%). Of the total, 344 (14%) of the babies were classified as LBW out of which 18% (5.2% of total) were VLBW and 4% (1.2% of total) were ELBW babies. Among the LBW babies, 73 (21%) were preterm with weight appropriate for gestational age (AGA), 15 (4%) were early term AGA, 27 (8%) were preterm SGA, and 229 (67%) were term SGA. As per Fenton 2013 reference chart, 612 (24.4%) babies in our study were SGA.

For continuous data, analysis was done with babies belonging to 34 to 40 weeks of gestation. As babies with gestational age < 34<sup>0/7</sup> weeks were sparsely represented, they were excluded from analysis. ► **Table 1** depicts the gestation and gender-wise mean birth weight with 95% CI. Female babies weighed less than male babies and the difference was significant in term babies ( $p = 0.34$  at 40 weeks, 0.32 at 39 weeks, and  $< 0.001$  at 38 weeks). No significant difference in weight was observed between the babies belonging to the two major socioeconomic status in our study, middle class and upper lower class ( $p = 0.2$ ). Mean weight of both male and female babies born to primiparae were significantly higher than the babies born to multiparae ( $p = 0.03$  and 0.02, respectively). When stratified by gestational age, the difference was significant beyond 37 weeks of gestation.

**Table 1** Mean difference in weight between male and female babies

GA	Gender	Mean	95% CI	N	SD	SE	Significance
34	Male	2,215	2,019–2,411	11	0.32359	0.09756	0.241
	Female	2,061	1,901–2,221	10	0.25309	0.08003	
35	Male	2,223	2,097–2,349	12	0.21960	0.06339	0.783
	Female	2,254	2,068–2,440	10	0.29489	0.09325	
36	Male	2,561	2,459–2,663	37	0.30865	0.05074	0.312
	Female	2,477	2,345–2,609	35	0.39267	0.06637	
37	Male	2,891	2,823–2,959	142	0.40448	0.03394	0.284
	Female	2,836	2,758–2,914	118	0.42410	0.03904	
38	Male	3,097	3,061–3,133	353	0.34449	0.01834	< 0.0001
	Female	2,965	2,923–3,007	336	0.39239	0.02141	
39	Male	3,113	3,077–3,149	405	0.35652	0.01772	0.032
	Female	3,054	3,012–3,096	384	0.40829	0.02084	
40	Male	3,201	3,141–3,261	183	0.39494	0.02920	0.034
	Female	3,119	3,069–3169	181	0.33619	0.02499	

Abbreviations: CI, confidence interval; GA, gestational age; SD, standard deviation; SE, standard error.

Majority of pregnant mothers in our study (61%) had anemia. PIH, GDM, oligohydramnios, hypothyroidism, and short stature were identified in 2.5, 3.4, 5.1, 4.4, and 2.3% of pregnant mothers, respectively. Mean birth weight of babies were compared between pregnancies with and without the observed comorbidities, stratified by gestational age. Term babies born to mothers with short stature and oligohydramnios were found to be significantly lower in weight, although these subsets were poorly represented in the preterm population.

Univariate analysis using generalized linear model with gestational age, gender, parity, PIH, oligohydramnios, short stature, and anemia as predictors revealed oligohydramnios ( $F = 33.24, p = 0.000$ ) and short stature ( $F = 10.69, p = 0.001$ ) as significant predictors apart from gestational age, gender, and parity. Anemia, though present in majority, was not

found to be a significant predictor. Babies with maternal oligohydramnios and short stature were excluded while estimating the percentile data.

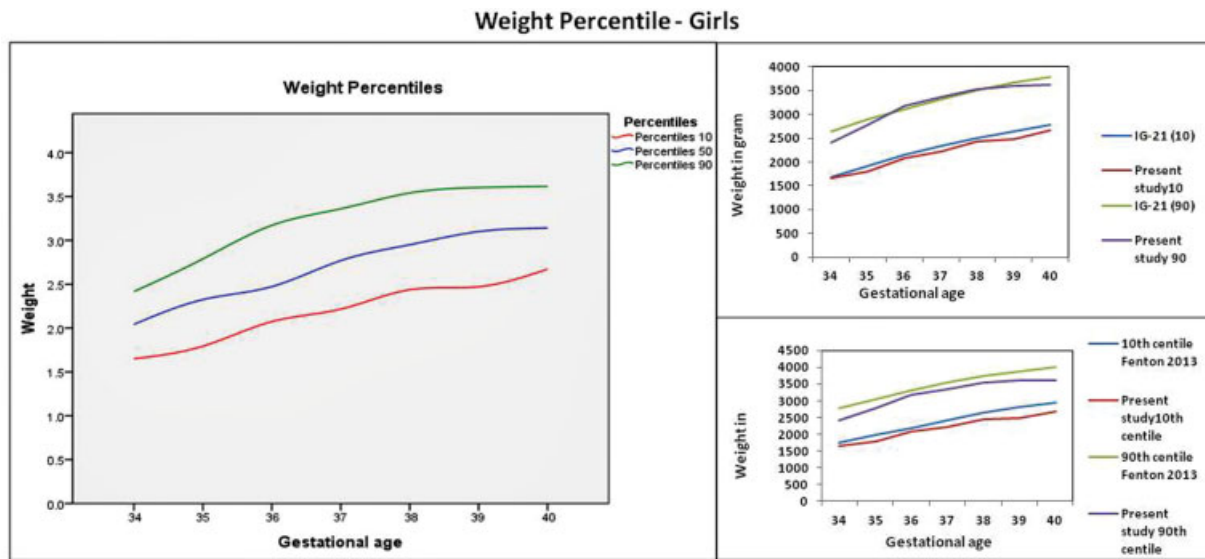
The 10th and 90th percentiles for weight of female and male babies of our study were lower than that of Fenton 2013 and IG-21 data in all gestational ages (→ **Table 2**). → **Figs. 1 and 2** show the smoothened percentile curves and its comparison with Fenton 2013 and IG-21 standards

By Fenton 2013 reference standard, 517 out of 2,217 babies born between 34 and 40 weeks of gestation in our study (23%) were SGA (95% CI: 22%, 25%). But as per the 10th percentile weight obtained from our study, only 227 out of these 2,217 babies (10%) were SGA (95% CI: 9%, 11%), which was significantly lesser ( $p < 0.0001$ ). Almost an equal proportion of babies in our study were born LGA too (8.5%) by the 90th percentile weight obtained from our data, whereas

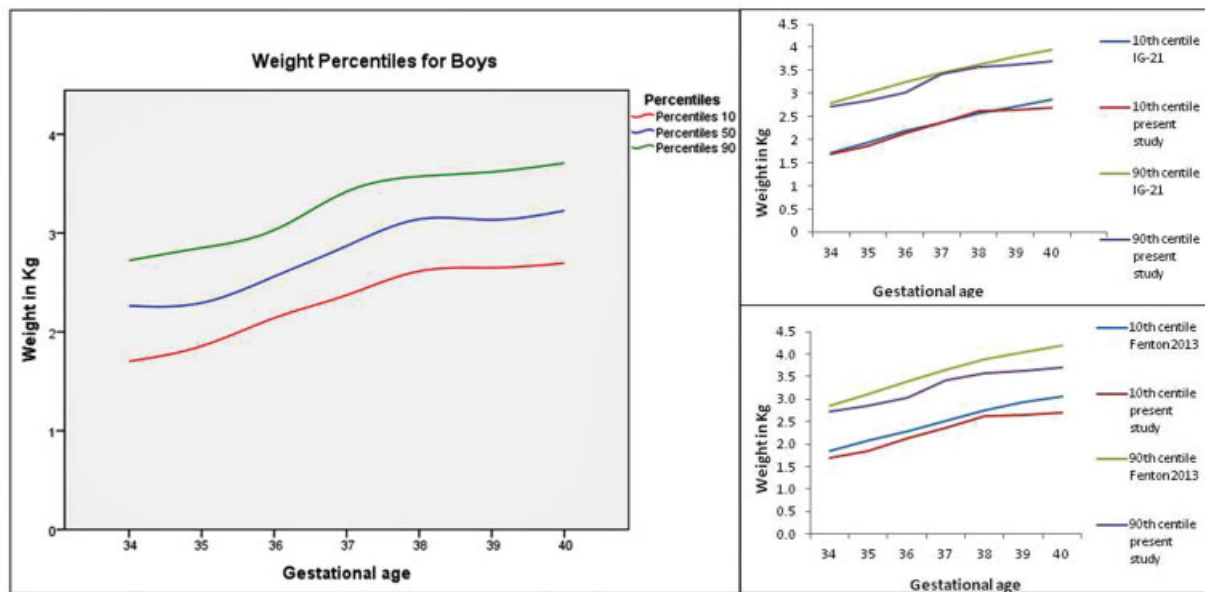
**Table 2** 10th and 90th percentiles of birth weight of female and male babies in our study, WHO Intergrowth-21 Consortium Growth Standards and Fenton 2013 reference standards

GA	Girls						Boys					
	10th percentile girls (g)			90th percentile girls (g)			10th percentile boys (g)			90th percentile boys (g)		
	PS	IG-21	F13	PS	IG-21	F13	PS	IG-21	F13	PS	IG-21	F13
34	1,650	1,680	1,752	2,416	2,640	2,764	1,700	1,710	1,839	2,720	2,790	2,843
35	1,793	1,920	1,991	2,788	2,890	3,050	1,860	1,950	2,079	2,850	3,030	3,121
36	2,073	2,140	2,197	3,171	3,120	3,296	2,140	2,180	2,297	3,030	3,250	3,390
37	2,216	2,330	2,416	3,360	3,320	3,532	2,370	2,380	2,529	3,420	3,450	3,660
38	2,437	2,500	2,639	3,540	3,510	3,736	2,610	2,570	2,755	3,600	3,630	3,876
39	2,471	2,650	2,807	3,602	3,660	3,878	2,650	2,730	2,925	3,620	3,790	4,034
40	2,672	2,780	2,938	3,616	3,800	4,014	2,690	2,880	3,059	3,710	3,940	4,181

Abbreviations: F13, Fenton reference standard 2013; GA, gestational age in weeks; IG-21, Intergrowth 21 standards; PS, present study.



**Fig. 1** Birth weight centiles (10th, 50th, 90th) of female babies in our study population and comparison with World Health Organization (WHO) Intergrowth-21 Consortium growth standards and Fenton 2013 reference standards.



**Fig. 2** Birth weight centiles (10th, 50th, 90th) of male babies in our study population and comparison with World Health Organization (WHO) Intergrowth-21 Consortium growth standards and Fenton 2013 reference standards.

only 1.5% were classified as LGA by the 90th percentile of Fenton 2013 reference standard. WHO IG-21 postnatal growth standards, however, identified 14% of these babies as SGA which is much lesser when compared with Fenton 2013 reference standard but significantly higher than the proportion obtained based on 10th percentile of the present study data ( $p < 0.0001$ ). IG-21 standards also identified higher proportion of LGA babies (5.5%) in the present study population when compared with Fenton's reference standard.

The 10th and 90th percentiles for weight of female and male babies of our study, further stratified by birth order and its comparison with similar data from a retrospective study

in India from CMC<sup>4</sup> is depicted in ► **Fig. 3**. The mean birth weight of babies born to primiparae from 37 weeks onwards is approximately 120 to 360 g higher for both male and female neonates in our study (► **Table 3**) when compared with the CMC study. The number of babies born below 37 weeks of gestation, when stratified by birth order, was not found to be adequate enough for comparison.

Univariate analysis of risk factors for SGA revealed parity ( $p = 0.004$ ) and oligohydramnios ( $p < 0.0001$ ) as significant risk factors. A multivariable logistic regression was performed to ascertain the effects of parity, oligohydramnios, and anemia on the likelihood of a newborn baby being SGA. The logistic regression model was statistically

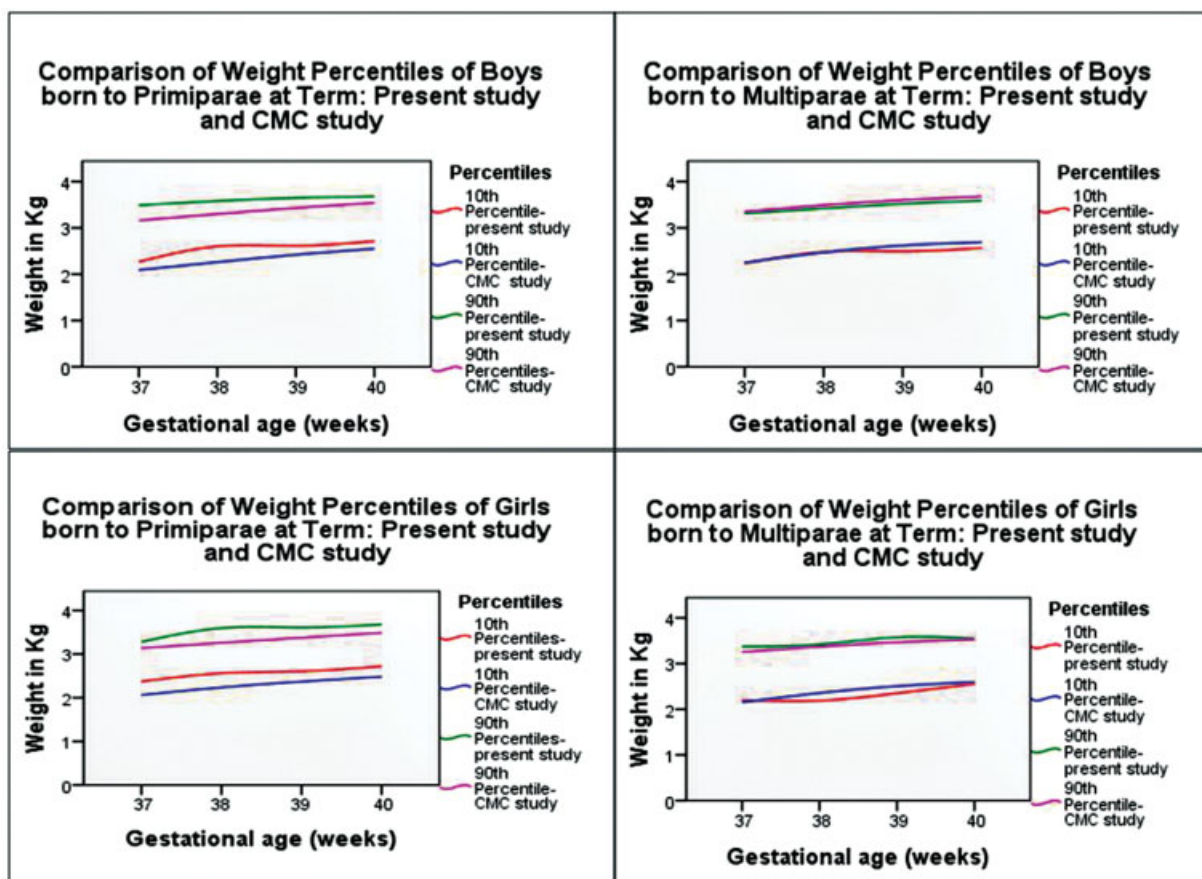


Fig. 3 Comparison of gender- and birth order-specific weight centiles between present study and Christian Medical College (CMC) study.

Table 3 Comparison of gender- and birth order-specific mean birth weight of term babies between present study and CMC Vellore study

Gestational age in weeks →				37	38	39	40
Mean birth weight in gram (SD)	Male	First born	PS	2,907 (430)	3130 (343)	3151 (367)	3250 (369)
			CMC	2,687 (384)	2774 (429)	2912 (388)	3083 (391)
			<b>p-value (z test)</b>	<b>0.0001</b>	<b>&lt; 0.0001</b>	<b>&lt; 0.0001</b>	<b>&lt; 0.0001</b>
		Later born	PS	2,869 (366)	3048 (341)	3060 (335)	3138 (420)
			CMC	2,808 (453)	2983 (395)	3119 (382)	3187 (390)
			<b>p-value (z test)</b>	0.23	0.03	0.03	0.3
	Female	First born	PS	2,843 (419)	3033 (385)	3089 (389)	3138 (330)
			CMC	2,637 (424)	2742 (397)	2856 (384)	2994 (404)
			<b>p-value (z test)</b>	<b>0.003</b>	<b>0.016</b>	<b>&lt; 0.0001</b>	<b>0.0003</b>
		Later born	PS	2,083 (434)	2,882 (387)	3,014 (427)	3,094 (344)
			CMC	2,692 (433)	2,867 (396)	2,981 (377)	3,078 (366)
			<b>p-value (z test)</b>	0.08	0.64	0.32	0.4

Abbreviations: CMC, Christian Medical College; PS, present study; SD, standard deviation. Note: p values in bold represent statistically significant differences.

significant,  $\chi^2 = 48.870$ ,  $p < 0.0001$ . The model correctly classified 74.7% of the babies. Chi-square for goodness-of-fit test was 21.305 at significance level of 0.095. Babies born to mothers with oligohydramnios are 2.5 times more likely to be SGA (95% CI: 1.67, 3.9). Primiparity was

associated with a significant reduction in likelihood of SGA babies compared with multiparity with a risk ratio of 0.719 (95% CI: 0.588, 0.878) (► Table 4). Also, the presence of anemia was associated with a reduction in risk of SGA babies compared with absence of anemia, which could be



**Table 4** Multivariable logistic regression analysis of independent variables predicting SGA

Weight category	Parameter	B	SE	Wald	df	Significance	Exp(B)	95% CI	
								Lower	Upper
SGA	Intercept	-0.834	0.098	72.732	1	0.000			
	Primiparity	-0.330	0.102	10.418	1	0.001	0.719	0.588	0.878
	Multiparity	0 <sup>a</sup>	.	.	0	.	.	.	.
	Oligohydramnios	0.920	0.216	18.140	1	0.000	2.509	1.667	3.902
	Adequate liquor	0 <sup>a</sup>	.	.	0	.	.	.	.
	Anemia	-0.344	0.106	10.515	1	0.001	0.709	0.575	0.873
	No anemia	0 <sup>a</sup>	.	.	0	.	.	.	.

Abbreviations: AGA, appropriate for gestational age; CI, confidence interval; df, degrees of freedom; SE, standard error; SGA, small for gestational age.

Note: The reference category is: AGA.

<sup>a</sup>This parameter is set to zero because it is redundant.

due to interaction of multiple predictor variables in the nonanemic group.

## Discussion

The study population is a representative sample from this geographical region, predominantly belonging to middle class (59%) and upper lower class (35%). The proportion of male babies (52%) was slightly higher than that of female (48%) babies and proportion of primiparae (57%) was higher compared with multiparae (43%). The prevalence of LBW babies corresponds to the National Family Health Survey (NFHS)-4 data<sup>5</sup> of Pondicherry (15%) but lower compared with the NFHS-4 national data. The prevalence of term SGA babies (24.4%) in our study is less compared with the national statistics as per the United Nations–Millennium Development Goals regional data, 2010 and the proportion of pre-term babies are also less (6%) compared with national statistics as per global, regional, and national estimates (13.6%), 2014.<sup>6,7</sup>

The study identified pregnancies complicated by anemia, PIH, GDM, oligohydramnios, and hypothyroidism as comorbidities in 61, 2.5, 3.4, 5.1, and 4.4%, respectively. The prevalence of anemia in our study population was slightly more than the national data (58.7%) but less than that of Tamil Nadu (69%), although the presence of anemia was not associated with increased risk of SGA babies in our study, the reason for which could be the presence of mild anemia in the majority. The systematic review and meta-analysis of 12 studies by the Child Health Epidemiology Reference Group states that moderate to severe maternal anemia rather than mild is associated with an SGA outcome.<sup>8</sup>

Birth order was found to be a significant predictor of birth weight in our study. Mean birth weight was found to be higher in first born term babies and multiparae were more likely to give birth to SGA babies. Few studies across the globe explored the importance of birth order and helped in the creation of gender- and birth order-specific percentile charts.<sup>9,10</sup> Only one Indian study by Kumar et al from CMC,

Vellore, India produced gender- and birth order-specific smoothed percentile charts based on retrospective data from approximately 20,000 institutional deliveries over 15 years from 1996 to 2010.<sup>4</sup> Since it was a retrospective study and more than a decade old, our study assumes significance as it is a prospective study and the study sample is focused on a well-defined geographic area from where no representative data exists in literature. When compared with the study by Kumar et al,<sup>4</sup> 10th and 90th centiles of the babies born at term to multiparae in our study corresponds fairly well with that of babies born to multiparae at CMC, whereas it is significantly higher for babies born to primiparae (► **Table 3**).

Most of the neonatal units in our country use international standards to classify neonates by birth weight into SGA, AGA, or LGA. When compared with the IG-21 Consortium chart,<sup>2</sup> the 10th percentile of neonates in our study population were lower in all gestational ages in both the sexes except at 38 weeks for boys with an average difference of less than 100 g. Although in female babies the 90th percentile corresponds well with the 90th percentile of IG-21, in male babies we observed a wide gap (► **Figs. 1 and 2**). When compared with the Fenton 2013 reference standards, both 10th and 90th percentile was much lower in our babies and the average difference being more than 200 g.

By Fenton 2013 reference standards, 517 out of 2,217 (23%) babies born between 34 and 40 weeks of gestation in our study were SGA. But as per the 10th percentile weight obtained from our study, only 227 out of these 2,217 babies (10%) were SGA. A significantly higher number of babies were identified as SGA by Fenton 2013 reference standards; however, the proportion of babies identified by IG-21 standards was only 14%, which is slightly higher compared with our study. Sebastian et al in their study on 36,674 babies in a South Indian population also found that only 8.4% of the babies were SGA based on their study data, which is similar to our study.<sup>11</sup>

Almost an equal proportion of babies in our study were LGA too (8.5%) by the 90th percentile weight obtained from

our data, whereas only 1.5% were LGA by the 90th percentile of Fenton 2013 reference standards. This is also similar to the finding of Jeyaseelan et al, who found that 9.4% of a total 35,718 babies were LGA based on their study data.<sup>12</sup> This finding leaves us with a question, whether extrapolating western standards for our babies will lead to overdiagnosis of SGA and underdiagnosis of LGA? Whether the small difference in 10th and 90th centiles of our study with the WHO IG-21 data are true or by chance, needs to be evaluated since Indian babies participating in IG-21 Consortium constituted only 12% of the study population and the newborn population selected from eight different regions globally were not homogeneous. Identifying SGA babies correctly is especially important since it is an important indicator of quality of health care of a nation. Though WHO IG-21 Consortium aimed at an uniform international standard derived from prospective longitudinal study with strict inclusion criteria, we need to be cautious of such generalization. Many Indian neonatal growth charts have been developed till date, most of which are cross-sectional observations of measurements at birth at different gestational ages. Earliest among them are by Ghosh et al from Safdarjung Hospital (1971),<sup>13</sup> Sing et al from AIMS, Delhi (1974),<sup>14</sup> and Mathai et al from CMC, Vellore (1996).<sup>15</sup> Kumar et al, CMC, Vellore (2013),<sup>4</sup> even after adjusting for maternal short stature, which is an important determinant of birth size, found that both 10th and 90th percentile was lower in Indian newborn babies across all gestational ages. Hence, extrapolating western data may lead to overdiagnosis of SGA babies and underdiagnosis of LGA babies. A higher proportion of LGA babies in our study as well as in another study by Jeyaseelan et al<sup>12</sup> is also an important finding and gives rise to a very pertinent question, whether this is related to the increasing incidence of obesity in our country.

Logistic regression analysis of risk factors associated with SGA revealed oligohydramnios and multiparity as significant risk factors (→ **Table 4**). The inverse relationship of anemia and SGA found in this analysis could be due to the interaction of multiple predictor variables in the nonanemic group. The strength of this study is that it has helped us to derive a reference standard for classifying birth weight of babies born in this region. The limitations of this study include the study being that of a single center's experience with a limited sample size, lesser number of premature babies, and cross-sectional study design.

To conclude, Indian babies may be overdiagnosed as SGA or underdiagnosed as LGA based on existing western standards in which our patient population is underrepresented. There is a need for gestational age, gender, as well as parity-specific regional growth charts for better characterization of anthropometric measures of Indian babies.

#### Authors' Contributions

A.P. performed the study with inputs on study design and study supervision by S.V., S.S., and S.P. Statistical analysis and interpretation of the data was done by S.V. The first

draft of this manuscript was written by S.V. with inputs from A.P., S.S., and S.P. All authors have seen and approved the final draft.

#### Funding

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#### Conflict of Interest

None declared.

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