Original Article

Birth anthropometry from a tertiary care hospital in Sri Lanka: Differs from the WHO growth standards

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Background and Objectives: The nutritional status of infants is assessed using the WHO growth references, based on the Multicenter Growth Reference Study (MGRS) in many countries including Sri Lanka. Birth parameters define infant growth curves. The aim of this study was to compare the birth anthropometric data of a healthy population of babies born in Colombo, Sri Lanka with the WHO MGRS birth data and determine its suitability for assessment of growth in this population. **Methods and Study Design:** Birth data were obtained as part of a study on longitudinal infant body composition from birth to 2 years from 2015-2019. Healthy babies, born to non-smoking mothers, >18 years old, with a singleton pregnancy at term, living in the study area and intending to breastfeed, were recruited. The Ethical Review Committee of the Faculty of Medicine, University of Colombo, approved the study. **Results:** Compared to WHO data, the mean birth weight (2.9±0.4 kg), length (48.2±2.7 cm) and head circumference (33.6±1.2 cm) of our study population (n=337) was significantly lower with a left shift in the z score distribution. This was despite similar background characteristics except for significantly lower income (USD 200) and lower maternal (154.2±9.0 cm) and paternal height (165±11.6 cm) in our study population. A significant change in birth parameters was only seen with maternal height when disaggregated. **Conclusions:** WHO birth parameters were significantly higher and underestimated the growth of healthy babies in Sri Lanka.

Key Words: birth anthropometry, WHO growth standards, Sri Lanka, infant nutrition, parental height

INTRODUCTION

The nutritional status of infants in many countries, including Sri Lanka, is assessed using the WHO growth standards based on the Multicenter Growth Reference Study (MGRS). Data were collected from approximately 8500 children in Brazil, Ghana, India, Norway, Oman and the USA, from 1997-2003.[1] The MGRS had a longitudinal sample (n=1743) recruited at birth and followed up for 24 months, and a cross-sectional sample (n=6697) from 18-71 months.[2] The WHO growth curves were designed to provide a single international standard representative of the best description of physiological growth for all breastfed children from birth to five years of age.[1]

A review by Natale et al. across 55 countries found significant differences in weight, height and head circumference in more than 20% of the children when compared with MGRS data. European countries were consistent outliers above the mean, in contrast to developing countries that were consistently below the mean.[3]

Previous studies undertaken in Sri Lanka by Abeywardena et al[4] in Kandy (4th highest income district) and Perera et al[5] in Gampaha (2nd highest income district), found significantly lower birth weight,[4,5] length[5] and head circumference[5] than the MGRS data.

Birth parameters define growth curves. The WHO growth curves provide an accurate representation of the norms of the population provided the birth parameters of that population are comparable to the WHO birth data. Therefore, it is important to compare birth parameters of a healthy study population with the WHO birth data to determine the appropriateness of using WHO growth charts to assess the nutritional status of that population.

Parental education, weight, height, body mass index (BMI), parity and socioeconomic status have been shown to affect birth anthropometry.[6-8]

The aim of this study was to compare the anthropometric data at birth of a healthy population of babies born in a tertiary care hospital in Colombo, Sri Lanka with the WHO data and determine the suitability of the WHO growth standard for assessment of growth in this population.

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METHODS

Study design and setting

Birth data was obtained as part of an observational, analytical, longitudinal, prospective cohort study on infant body composition from birth to 2 years conducted at the University Unit of the De Soysa Hospital for Women, Colombo, Sri Lanka, a tertiary care maternity hospital, from July 2015 to December 2019.

Sri Lanka is a middle-income country with impressive health statistics, including a maternal mortality rate of 32.0/100,000 live births, and a neonatal mortality rate of 6.5/1000 live births.[9] Colombo is the most populous amongst the 25 administrative districts with 2,310,136 inhabitants, 11.4% of the total Sri Lankan population.[10] Colombo has the highest monthly household income[11] and the lowest poverty head count index,[12] where 98.2% of deliveries occur in hospitals.[13]

Study population

Trained research assistants visited the obstetric wards of the University Unit twice a day on all week-days, approached all pregnant women admitted between gestational age (GA) of 37 and 41+6 weeks, and screened those who consented to join the study. All consecutive mothers and babies who fulfilled the criteria were recruited via purposive sampling.

Inclusion criteria

Women with a singleton pregnancy, aged more than 18 years, living in the Colombo District, intending to breastfeed and consented to attend monthly follow-up, were recruited prior to delivery. Their newborns were included in the study after screening for any morbidity.

Exclusion criteria

Mothers with a history of smoking or passive smoking were excluded. Babies with an Apgar score <8 at 5 minutes of age, congenital anomalies, disease conditions affecting growth or requiring admission to the neonatal unit, were excluded.

Sample size calculation

Assuming a pooled standard deviation (SD) of 0.44 units, the study required a minimum sample size of 43 for each group, to achieve a power of 90% and a level of significance of 5%, for detecting a true difference in the mean birth weight of males between Jananthan et al[14] and the WHO growth standard,[15] of -0.31(3.04 - 3.35) units.

Data collection

Data was collected using an interviewer-administered questionnaire. GA was derived by antenatal ultrasound scan measurements of crown rump length at 8-13 weeks period of amenorrhea, failing which the biparietal diameter at 13-20 weeks, failing which using the last regular menstrual period.

Anthropometry

Birth weight was measured to the nearest 5 g using an electronic scale (Seca 334) which was calibrated twice weekly. Birth length, occipito-frontal-circumference (OFC) and parental height was measured, to the nearest millimeter, using an infantometer (Seca 417), a non-stretchable measuring tape (Seca 212) and a stadiometer (Seca 213), respectively (Seca Gmbh, Hamburg, Germany). All measurements were performed within 12-24 hours by the same lead investigator (intra-observer mean error (ME) = 0.01), according to techniques in the INTERGROWTH-21st study,[16] who was trained by an International Society for Advancement of Kinanthopometry (ISAK) Level two accredited consultant to the International Atomic Energy Agency(IAEA) on anthropometry and standardization. Each measurement was repeated independently by a second trained anthropometrist (intra-observer ME) = (0.02-0.04). If the difference between the two measurements exceeded 50 g (birth weight), 7 mm (length) and 5 mm (OFC), both observers independently took that measurement again and, if necessary, a third time, identical to the procedure used in the MGRS study.[17] Standardisation was done every 6 months and the inter-observer ME was 0.009, 0.22 and 0.18-0.26 for weight, length and OFC, respectively.

Ethics approval

The Ethics Review Committee of the Faculty of Medicine, University of Colombo, approved the study (EC-14-145).

Statistical analysis

Mean, median and SD was calculated using SPSS version 26.0 for MacBook. Z scores were obtained from the online WHO Anthro Survey Analyser for MacBook from www.who.int. ANOVA and the post hoc Tukey tests were applied to determine the differences between means of the MGRS sample and our study population as well as for subgroup analysis. Low birth weight (LBW) proportions were compared between subgroups using chi square test.

RESULTS

In our study population, screening was carried out in 4140 women, of which 450 (10.9%) refused and 3263 (78.8%) were ineligible. The commonest reason for ineligibility (88%) was living outside the study area. A total of 427 women (10.3%) met the inclusion criteria and enrolled in the study. Only 344 consented to participate in the study after delivery, due to difficulties in attending the monthly follow-up required for the longitudinal study. Seven records were not included due to incomplete birth data, resulting in a study population of 337 newborn babies, 180 males and 173 females. The MGRS study had an overall enrollment rate of 12.7%, similar to our enrollment of 10.3%, where Brazil (6.5%) and Oman (6.0%) had lower enrollment rates than our study population. Comparison of the enrollment characteristics between the Sri Lankan study population and the WHO-MGRS study longitudinal sample are given in Table 1.

Sociodemographic details of babies in the Sri Lankan study population compared to that of the WHO-MGRS study longitudinal sample are given in Table 2. Our study population in comparison to MGRS, who used income and education as selection criteria, had similar parity and maternal age, education comparable to that of Brazil, with significantly lower (p<0.001) parental heights and monthly family income.

Table 1. Characteristics at enrollment in comparison with WHO MGRS study population†

	Sri Lanka (n=337)	Brazil (n=310)	Ghana (n=329)	India (n=301)	Norway (n=300)	Oman (n=295)	USA (n=208)	MGRS overall
Screened, n	4140	4801	2057	692	836	4957	398	11963
Enrolled, n%	427 (10.3)	310 (6.5)	329 (16.0)	301 (43.5)	300 (35.9)	295 (6.0)	208 (52.3)	1743 (12.7)
Refusals, n%	450 (10.9)	84 (1.7)	47 (2.3)	47 (2.3)	134 (16)	234 (4.7)	67 (16.8)	647 (4.7)
Ineligible, n%	3263 (78.8)	4407 (91.8)	1681 (81.7)	310 (43.5)	402 (48.1)	4428 (89.3)	123 (30.9)	11351 (82.6)
Reason for ineligibility%								
Outside study area	88	24.9	11.4	6.2	14.2	31.2	0	22.8
Multiple births	1.5	2.2	0.8	0	2.9	1.3	0.8	1.5
GA out of range	8.5	8.7	1.5	4.5	6.2	6.5	3.3	6.3
Perinatal morbidity	1.5	6.1	1.3	1.7	12.2	5.0	5.8	5.1
Mother is a smoker	0.0	19.0	0.1	0.4	9.2	0.6	1.5	7.5
Low SES	0.5	54.3	74.2	24.4	0.0	47.3	0.8	48.4
Other	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1

GA: gestational age, SES: socioeconomic status.
†Adapted from MGRS longitudinal data with permission.[2]

Table 2. Comparison of sociodemographic data with WHO, MGRS study population†

	Sri Lanka (n=337)	Brazil (n=310)	Ghana (n=329)	India (n=301)	Norway (n=300)	Oman (n=295)	USA (n=208)
Live births; median (range)	2 (1-6)	2 (1-7)	2 (1-8)	1 (1-3)	2 (1-5)	2 (1-12)	1 (1-5)
<3 children	74.0	81.6	68.7	96.7	87.7	51.4	84.1
Primiparous	44.0	49.0	38.1	53.5	55.0	27.8	53.4
Parental characteristics (mean±SD)							
Years of education							
Mother	10.9±2.5	11.1±3.5	15.1±2.7	17.5±1.5	15.4±2.6	11.9±3.3	16.7±2.1
<10	21.2	33.6	2.7	0	1.3	24.8	0
10-14	75.4	41.9	36.9	0.6	31.7	52.2	12.5
15-19	3.4	24.5	56.4	90.4	64.0	22.7	75.5
>20	0	0	4.0	9.0	3.0	0.3	12.0
Father	11.0±2.4	10.2±3.6	18.1±3.0	17.4±1.8	15.2±2.8	12.8±3.6	16.9±2.6
<10	16.6	39.4	0.9	0	2.0	19.7	1.5
10-14	80.8	44.5	6.5	1.0	33.3	46.4	14.4
15-19	2.6	16.1	65.0	87.0	62.0	33.2	64.9
>20	0	0.0	27.6	12.0	2.7	0.7	18.8
Maternal age (years)	29.0± 5.7	28.3±6.3	30.8±4.0	28.9±3.5	30.6±4.4	27.5±4.9	30.8±4.8
<20	2.8	11	0	0	0	3.1	1.4
20-24	23.8	15.8	4	11.3	9	24.7	7.2
25-29	26.3	29.4	36.2	43.5	30.3	44.1	30.3
30-34	27.7	27.7	39.8	38.5	42.3	17.6	37.5
>35	19.4	16.1	20.0	6.7	18.4	10.5	23.6
Maternal height (cm)	154.2±9.0	161.1±6.0	161.9±5.2	157.6±5.4	168.7±6.6	156.6±5.5	164.5±6.9
Paternal height (cm)	165±11.6	173.6±6.9	173.0±6.6	172.7±6.3	182.2±6.7	170.4±6.4	178.9±7.4
Socio economic factors							
Median monthly income (USD)	200	1,019	739	957	6,296	2,938	5,000
Piped Water	100	100	100	100	100	100	100
Flush Toilet	100	100	98.8	100	100	100	100
Refrigerator	71.6	100	98.5	100	100	100	100
Gas/Electric Cooker	86.1	100	98.2	100	100	100	100
Telephone	99.1	85.2	81.4	99.0	100	98.3	100
Car	12.7	71	81.4	90.4	83.3	97.3	99.0

All responses are percentages unless otherwise specified.
†Adapted from MGRS longitudinal data with permission.[2]

Table 3. Comparison of baseline characteristics with the MGRS study population †

	Sri Lanka (n=337)	Brazil (n=310)	Ghana (n=329)	India (n=301)	Norway (n=300)	Oman (n=295)	USA (n=208)	All (n=1743)
Male%	51.4	52.3	48.9	54.2	53.3	50.2	50.0	51.5
Apgar @ 5min	10.0±0.1	9.7±0.5	9.2±0.9	9.1±0.6	9.4±0.6	9.8±0.6	8.9±0.6	9.4±0.7
Vaginal delivery%	62.6	46.1	72.9	59.5	90.0	85.8	87	72.6
Caesarean delivery%	37.4	53.9	27.1	40.5	10.0	14.2	13	27.4
LBW %	16.3	1.9	1.5	4.7	0.7	2.7	0.5	2.1
Male	13.9							
Female	18.5							
Birth parameters (mean±SD)								
Weight, kg	2.9±0.4	3.3±0.4	3.3±0.4	3.1±0.4	3.6±0.5	3.2±0.4	3.6±0.5	3.3±0.5
Male	3.0±0.5							3.3±0.5
Female	2.8±0.4							3.2±0.4
Length, cm	48.5±2.3	49.6±1.9	49.4±1.9	49.0±1.8	50.4±1.9	49.2±1.7	49.7±2.0	49.6±1.9
Male	49.0±2.4							49.9±1.9
Female	47.9±2.1							49.1±1.9
OFC, cm	33.8±1.3	34.6±1.1	34.3±1.2	33.8±1.2	34.9±1.2	33.4±1.0	34.2±1.3	34.2±1.3
Male	34.1±1.3							34.5±1.3
Female	33.5±1.2							33.9±1.2

LBW: low birth weight, OFC: occipito-frontal circumference.
†Adapted from MGRS longitudinal data with permission.

Table 4. Birth anthropometry z scores of the Sri Lankan study population

	LAZ	WAZ	WLZ	BMIZ
Mean	-0.56	-0.87	-0.68	-0.91
SD	1.21	0.98	1.10	1.13
% below -2SD	11	11.3	7.7	1.7
% below -3SD	1.1	1.7	0.9	0.0
Skewness	0.43	0.02	-0.29	0.81
Kurtosis	3.12	-0.06	2.63	3.34

LAZ: length for age z-score, WAZ: weight for age z-score, WLZ: weight for length z-score, BMIZ: BMI for age z-score

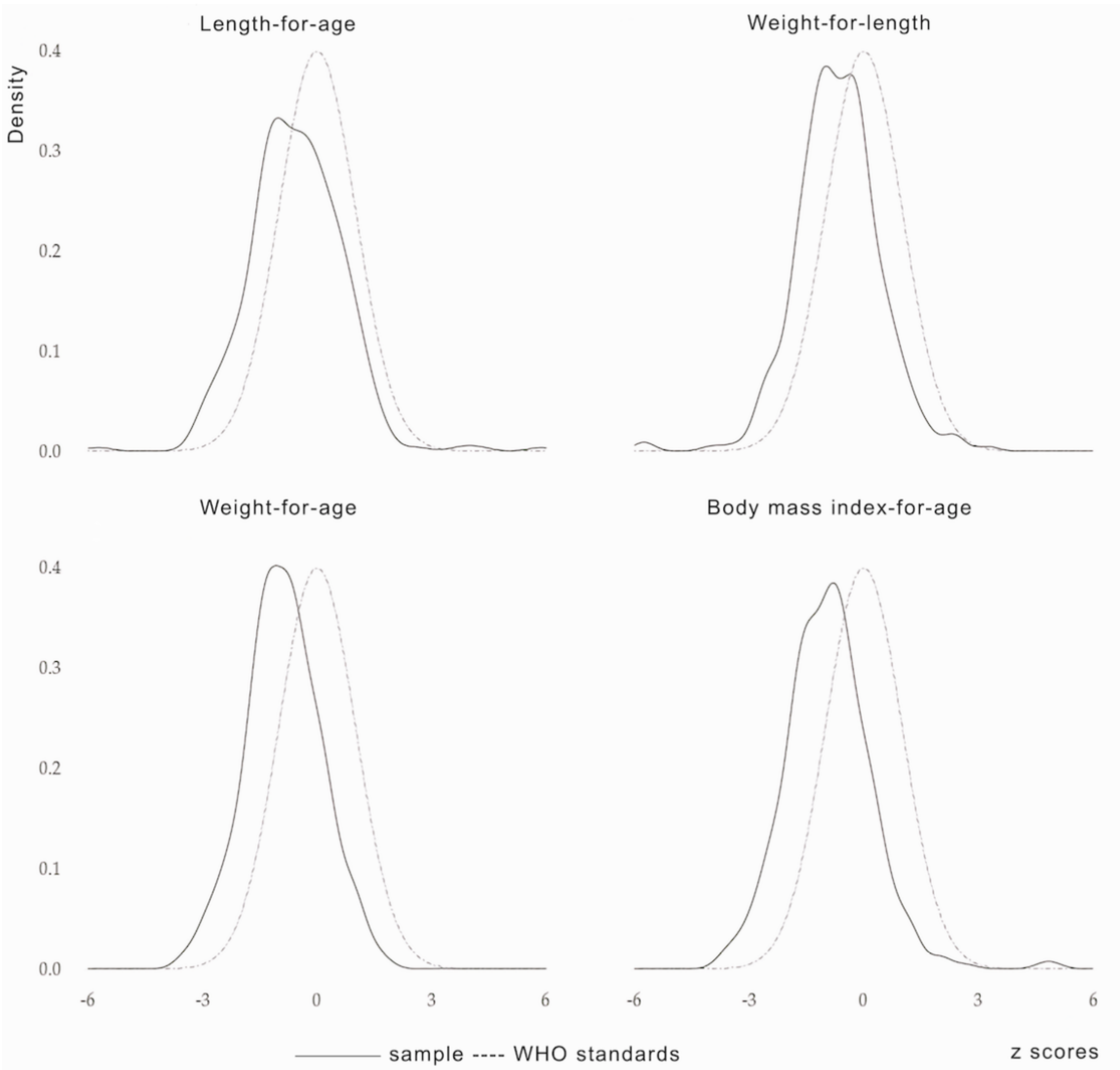

Figure 1. Z-score distribution of birth anthropometry in the Sri Lankan study population (continuous line) compared with the WHO reference values (interrupted lines).

Table 5. The effect of family income on birth parameters of Sri Lankan infants

Quintile	%	Weight (kg)	Length (cm)	OFC (cm)	LBW%
1	22.4	2.9±0.4	48.6±2.6	33.4±1.8	23.2
2	42.7	2.9±0.5	48.4±2.8	33.8±1.4	46.4
3	19.3	2.9±0.4	48.5±2.1	33.8±1.2	12.5
4	9.7	2.8±0.4	48.1±3.2	33.6±0.9	10.7
5	5.9	2.9±0.4	48.3±2.9	33.6±1.4	7.1
Overall	100	2.91±0.4	48.4±2.6	33.8±1.4	100
p value		0.831	0.953	0.770	0.713

OFC: occipito frontal circumference, LBW: low birth weight.
Monthly Income was disaggregated according to national wealth quintiles in 2016.[11]

Comparison of the baseline characteristics with the WHO-MGRS study longitudinal sample is shown in Table 3. Our study population had the highest percentage of LBW babies, despite similar baseline characteristics. The mean birth weight ($p<0.001$) and length ($p<0.05$) of Sri Lankan babies were lower than all the MGRS countries, in contrast to the OFC which was significantly higher than Oman ($p=0.0013$) and similar to that of India, despite being significantly lower than the other MGRS countries ($p<0.05$).

Our study population, showed a normal distribution of z-scores as shown in Figure 1 and Table 4. When compared to the WHO-MGRS population, the mean length-for-age z score (mean=-0.56, SD=1.21) of our study population is lower. This could be due to lower birth lengths in our population. In addition, there is a slight right skewness of length distribution (skewness=0.43) (Figure 1). The distribution patterns of weight-for-length z score (WLZ) (mean=-0.68, SD=1.1), show a slight left-sided skewness (skewness=-0.29) and BMI z score (BMIZ) (mean=-0.91, SD=1.13), a right-sided skewness (skewness=0.81). Weight-for -age (WAZ) (mean=-0.87, SD=0.98) curve does not show a marked change in the

Table 6. The effect of maternal height on birth parameters of Sri Lankan infants

Maternal Height(cm)	%	Weight (kg)	Length(cm)	OFC (cm)	LBW‡%
<145	5.7	2.7±0.4	47.7±3.1	33.4±1.0	7.7
145-150	15.8	2.8±0.4	47.9±2.3	33.4±1.2	17.3
151-155	29.3	2.9±0.4	48.2±2.8	33.8±1.6	26.9
156-160	26.3	2.9±0.5	48.6±3.1	34.0±1.4	28.8
161-165	16.2	3.0±0.4	49.0±2.0	34.1±1.3	15.4
166-170	6.4	3.0±0.4	49.2±2.4	34.0±1.0	3.8
171-175	0.3	4.1±0	51.0±0	36.5±0	0
Overall	100	2.9±0.5	48.4±2.7	33.8±1.4	100 (n=52)
p value		0.003	0.213	0.038	0.947

OFC: occipito frontal circumference, LBW: low birth weight.

Table 7. The effect of paternal height on birth parameters of Sri Lankan infants

Paternal Height(cm)	%	Weight (kg)	Length(cm)	OFC (cm)	LBW%
150-155	6.7	2.8±0.6	47.9±2.1	34.0±1.1	15.4
156-160	4.0	2.9±0.1	50.2±1.3	33.6±0.8	0
161-165	30.7	2.9±0.5	49.1±2.4	34.0±1.5	30.8
166-170	30.7	2.8±0.5	48.7±2.5	33.8±1.6	38.5
171-175	17.3	3.1±0.4	49.9±1.7	34.4±1.0	7.7
176-180	9.3	2.8±0.4	47.4±2.3	33.5±1.4	7.7
181-185	1.3	3.715±0	51.20±0	36.1±0	0
Overall	100	2.9±0.5	48.9±2.3	34.0±1.4	100
p value		0.453	0.236	0.608	0.699

OFC: occipito frontal circumference, LBW: low birth weight.

symmetry of the curve, indicating only a left-shift of birth weights (skewness=0.02).

Subgroup analysis between the different income quintiles, categorized using the Health Income and Expenditure Survey (HIES) 2016,[11] as given in Table 5, showed no significant difference in the birth weight, length, OFC or LBW percentage in our study population.

Subgroup analysis on parental height (Table 6 and 7), revealed that an increase in maternal height resulted in a significant increase in the birth weight (p=0.003) and OFC (p=0.038) but not length (p=0.213), while paternal height did not have a significant effect on birth weight (p=0.453), OFC (p=0.608) or length (p=0.236).

DISCUSSION

The WHO-MGRS longitudinal study population was followed up at home, whereas our study population from Colombo, Sri Lanka, attended monthly follow-up at the study centre. The requirement to attend follow-ups monthly and live in the study area, resulted in the large number of refusals and ineligible participants, as many were referred for specialized care from all over the country.

Our study population, in comparison to MGRS, had the highest proportion of LBW babies, lowest mean birth weight and length in contrast to the OFC, which was comparable to two MGRS countries but lower than others. Significant differences were also noted between MGRS countries with regard to all birth parameters. Natale et al also found that 11 of 55 countries had significantly different growth parameters to the WHO-MGRS standards.[3]

The monthly income and parental heights of our study population were significantly lower than all the MGRS countries, despite the selection criteria being very similar. Parental height was also significantly different within MGRS countries. In our study population, subgroup analysis of income quintiles and paternal height revealed that it had no effect on the birth parameters. The lack of correlation between birth anthropometry and income may be attributed to most of our study population being within the 1st and 2nd income quintiles, representing the lower socioeconomic groups. In contrast, maternal height was shown to affect birth weight and OFC, similar to Witter et al. where it was found to affect birth weight and length.18 This would explain the significant differences in birth parameters within the MGRS country data, despite controlling for socioeconomic factors at recruitment.

Comparative analysis was undertaken using the published summary data of the MGRS. We were unable to standardize the MGRS data for income and parental height, due to the unavailability of the MGRS raw data.

Birth weight, length, and OFC of our study population were significantly lower than the WHO-MGRS references. This results in incorrect interpretation of national nutritional indices when using the WHO growth charts on country data. It also questions the arbitrary cut-off of 2.5 kg used for LBW across all populations. Many babies would be falsely labeled as underweight and stunted with resultant overfeeding in order to achieve the growth standard in the WHO growth chart. This practice would place these babies at higher risk of obesity and associated health risks, including non-communicable diseases.

Our data suggest that disparity in birth anthropometry among countries could be due to intrinsic differences such as maternal height, rather than extrinsic differences such as socioeconomic factors.

This finding highlights the importance of each country having growth standards based on the country's unique characteristics. The findings of this study also reinforce the importance of the assessment of the quality of growth or body composition in terms of fat mass and fat-free mass, alongside traditional anthropometric measures such as weight and length.

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AUTHOR DISCLOSURES

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REFERENCES

1. de Onis M, Garza C, Victora CG, Bhan MK, Norum KR. The WHO Multicentre Growth Reference Study (MGRS): Rationale, planning, and implementation. Food Nutr Bull. 2004;25(Suppl 1):S3-S84. doi: 10.1177/15648265040251S104.
2. WHO multicentre growth reference study group. Enrolment and baseline characteristics in the WHO Multicentre Growth Reference Study. Acta Pædiatr Suppl. 2006;450:7-15.doi: 10.1111/j.1651-2227.2006.tb02371.x.
3. Natale V, Rajagopalan A. Worldwide variation in human growth and the World Health Organization growth standards: a systematic review. BMJ Open. 2014;4:e003735. doi: 10.1136/bmjopen-2013-003735.
4. Abeyagunawardena IA, Abeynayake A, Anuththara T, Alawaththegama K, Amanda S, Abeyrathne V et al. Is it appropriate to use WHO Multicentre Growth Reference Study standards to assess the growth parameters of Sri Lankan babies? A single-centre cross-sectional study. BMJ Paediatrics Open. 2017;2:e000174. doi: 10.1136/bmjpo-2017-000174.
5. Perera PJ, Ranathunga N, Fernando MP, Warnakulasuriya TD, Wickremasinghe RA. Growth parameters at birth of babies born in Gampaha district, Sri Lanka and factors influencing them. WHO South-East Asia J Public Health. 2013;2:57-62. doi: 10.4103/2224-3151.115845.
6. Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. Bull World Health Organ. 1987;65:663-737.
7. Metgud CS, Naik VA, Mallapur MD. Factors affecting birth weight of a newborn--a community based study in rural Karnataka, India. PLoS One. 2012;7:e40040. doi: 10.1371/journal.pone.0040040
8. Makhoul IR, Awad E, Tamir A, Weintraub Z, Rotschild A, Bader D et al. Parental and perinatal factors affecting childhood anthropometry of very-low-birth-weight premature infants: a population-based survey. Acta Pædiatrica. 2009;98:963-9. doi: 10.1111/j.1651-2227.2009.01242.x
9. Family Health Bureau Sri Lanka. Statistics. 2019/03/12. [cited 2020/04/07]; Available from: https://fhb.health.gov.lk/index.php/en/statistics.
10. Department of Census and Statistics. Percentage distribution of population according to district. Census of population and Housing 2012. Sri Lanka: Ministry of Finance and Planning; 2014. pp. 85. [cited 2020/04/07]; Available from: http://www.statistics.gov.lk/PopHouSat/CPH2011/Pages/Activities/Reports/CPH_2012_5Per_Rpt.pdf.
11. Department of Census and Statistics. Percentage of households and share of income to total household income by national household income decile and sector – 2016. Sri Lanka Household Income and Expenditure Survey 2016. Ministry of National Policies and Economic Affairs Sri Lanka; 2018. pp. 16. [cited 2020/04/07]; Available from: http://repo.statistics.gov.lk/bitstream/handle/1/784/HIES2016_FinalReport.pdf?sequence=1&isAllowed=y.
12. Department of Census and Statistics. Percentage of households and share of income to total household income by national household income decile and sector – 2016. Sri Lanka Household Income and Expenditure Survey 2016. Sri Lanka: Ministry of National Policies and Economic Affairs; 2018. pp. 41 [cited 2020/04/07]; Available from: http://repo.statistics.gov.lk/bitstream/handle/1/784/HIES2016_FinalReport.pdf?sequence=1&isAllowed=y.
13. Rajapaksa L, Senanayake L, Galwaduge C, Hemachandra N, Rowel D, Silva P. National Emergency Obstetric and Neonatal Care Needs Assessment. Country report 2012. Family Health Bureau, Ministry of Health; 2014. pp. 184. [cited 2020/04/07]; Available from: https://www.maternalnutritionsouthasia.com/wpcontent/uploads/country_report_2012.pdf.
14. Jananthan R, Wijesinghe DGNG and Sivananthawerl T. Maternal anthropometry as a predictor of birth weight. Tropical Agricultural Research. 2009:21:89-98. doi: 10.4038/tar.v21i1.2590.
15. World Health Organisation. The WHO Child Growth Standards; C2020. [cited 2020/04/07]; Available from: https://www.who.int/childgrowth/standards/wfa_boys_0_13_zscores.txt.
16. Cheikh Ismail L, Knight H, Ohuma E et al. Anthropometric standardisation and quality control protocols for the construction of new, international, fetal and newborn growth standards: the INTERGROWTH-21st Project. BJOG 2013; 120:48-55. doi: 10.1111/1471-0528.12127.
17. de Onis M, Onyango AW, den Broeck JV, Chumlea WC, Martorell R. The WHO Multicentre Growth Reference Study (MGRS): Measurement and standardization protocols for anthropometry used in the construction of a new international growth reference. Food Nutr Bull. 2004; 25(Suppl1):S27-36. doi: 10.1177/15648265040251S105.
18. Witter FR, Luke B. The effect of maternal height on birth weight and birth length. Early Hum Dev. 1991;25:181-6. doi:10.1016/0378-3782(91)90114-I.