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Assessment of differences in linear growth among populations in the WHO Multicentre Growth Reference Study

WHO MULTICENTRE GROWTH REFERENCE STUDY GROUP[1,2]

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Abstract

Aim: To assess differences in length/height among populations in the WHO Multicentre Growth Reference Study (MGRS) and to evaluate the appropriateness of pooling data for the purpose of constructing a single international growth standard. *Methods:* The MGRS collected growth data and related information from 8440 affluent children from widely differing ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman and the USA). Eligibility criteria included breastfeeding, no maternal smoking and environments supportive of unconstrained growth. The study combined longitudinal (birth to 24 mo) and cross-sectional (18–71 mo) components. For the longitudinal component, mother–infant pairs were enrolled at delivery and visited 21 times over the next 2 y. Rigorous methods of data collection and standardized procedures were applied across study sites. We evaluate the total variability of length attributable to sites and individuals, differences in length/height among sites, and the impact of excluding single sites on the percentiles of the remaining pooled sample. *Results:* Proportions of total variability attributable to sites and individuals within sites were 3% and 70%, respectively. Differences in length and height ranged from −0.33 to +0.49 and −0.41 to +0.46 standard deviation units (SDs), respectively, most values being below 0.2 SDs. Differences in length on exclusion of single sites ranged from −0.10 to +0.07, −0.07 to +0.13, and −0.25 to +0.09 SDs, for the 50th, 3rd and 97th percentiles, respectively. Corresponding values for height ranged from −0.09 to +0.08, −0.12 to +0.13, and −0.15 to +0.07 SDs.

Conclusion: The striking similarity in linear growth among children in the six sites justifies pooling the data and constructing a single international standard from birth to 5 y of age.

Key Words: *Childhood growth, growth curves, growth standards, height, length*

Introduction

Child growth charts are among the most commonly used tools for assessing the health and nutritional status of individual infants and children, and the general well-being of their communities [1]. They are useful in determining the degree to which physiological needs for growth and development are met during the fetal and childhood periods. Recognizing the shortcomings of the current National Center for Health Statistics/World Health Organization (NCHS/WHO) international growth reference [1,2], the WHO began planning in 1994 for new references that reflect how children *should* grow in all countries rather than merely describing how they grew at a particular time and place [3,4]. This prescriptive approach explicitly recognizes that growth references are often used as standards, that is, as tools that enable value judgments [5].

The WHO Multicentre Growth Reference Study (MGRS) collected primary growth data and related information from 8440 affluent children from widely differing ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman and the USA) [6]. An international sampling frame was selected on the basis of scientific and health advocacy considerations. Scientifically, it is well established that children from diverse ethnic groups grow very similarly during the first 5 y of life when their physiological needs are met and environments support healthy development [7–10]. Health advocacy considerations were also strong in the MGRS design. The development of a growth standard based on children from different world regions has the potential to yield an effective tool for child health advocacy by underscoring the fact that children in all countries *can* achieve their full growth potential when their nurturing follows health

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recommendations and care practices associated with healthy outcomes [5].

This paper evaluates differences in length/height from birth to 5 y of age within and among the MGRS sites. It addresses two issues fundamental to the construction of the new standards: the potential for linear growth in diverse ethnic populations whose health and care needs are met, and the appropriateness of a single international standard for this age group. Length/height was selected as the most suitable measure to assess population differences of possible genetic or environmental origin among children of well-off families. Linear growth is normally distributed and resistant to skewing in response to excessive energy intakes, unlike weight which is more "plastic" in response to overnutrition. On the other hand, linear growth can be affected negatively and profoundly by environmental factors such as diet and infection, but it is unlikely that these would be relevant in the affluent populations selected for this study.

Methods

Design

The MGRS (July 1997–December 2003) was a population-based study covering the cities of Davis, California, USA; Muscat, Oman; Oslo, Norway; and Pelotas, Brazil; and selected affluent neighbourhoods of Accra, Ghana, and South Delhi, India. The MGRS protocol and its implementation in the six sites have been described in detail elsewhere [6,11–16]. Briefly, the MGRS combined a longitudinal study from birth to 24 mo with a cross-sectional study of children aged 18 to 71 mo. In the longitudinal study, mothers and newborns were screened and enrolled at birth and visited at home a total of 21 times on weeks 1, 2, 4 and 6; monthly from 2–12 mo; and bimonthly in the second year. Data were collected on anthropometry, motor development, feeding practices, child morbidity, perinatal factors, and socio-economic, demographic and environmental characteristics. The analyses in this paper focus on recumbent length measurements from the longitudinal sample and standing height measurements from the cross-sectional sample.

The study populations had socio-economic conditions favourable to growth and low mobility, with ≥20% of mothers following feeding recommendations and having access to breastfeeding support [6]. Individual inclusion criteria were: the absence of health or environmental constraints on growth, mothers willing to follow MGRS feeding recommendations (i.e. exclusive or predominant breastfeeding for at least 4 mo; introduction of complementary foods by the age of 6 mo; partial breastfeeding continued for at least 12 mo), no maternal smoking before and after delivery, single term birth, and absence of significant morbidity [6]. As part of the site-selection process in Ghana, India and Oman, surveys were conducted to identify socio-economic characteristics that could be used to select groups whose growth was not environmentally constrained [17–19]. Local criteria for screening newborns, based on parental education and/or income levels, were developed from those surveys [12,13,15]. Pre-existing survey data were available from Brazil, Norway and the United States for this purpose [11,14,16]. Term low-birthweight infants (2.3%) were not excluded since it is likely that, in well-off populations, such infants represent small but normal children and their exclusion would have artificially distorted the standards' lower percentiles. Eligibility criteria for the cross-sectional study were the same as those for the longitudinal study with the exception of infant feeding practices. A minimum of 3 mo of any breastfeeding was required for participants in the study's cross-sectional component.

The total sample size for the longitudinal and cross-sectional studies in all six sites was 8440 children. Length (longitudinal sample) and height (cross-sectional sample) were measured at all sites following standardized procedures using, respectively, a Harpenden Infantometer and Stadiometer. The detailed protocols followed to obtain anthropometric measurements and to ensure high-quality data are described elsewhere [6,20,21].

Analytical methods

The analyses of the MGRS longitudinal study are based on measurements taken at birth, and at 6, 12, 18 and 24 mo of all enrolled children. Analyses of the cross-sectional study were conducted at the following age intervals: 24–26 mo, 36–38 mo, 48–50 mo and 60–62 mo. Cross-sectional measurements obtained in the indicated age intervals were adjusted to the midpoint of each interval using linear regression and assumed equal growth rates for all children within each interval.

Heterogeneity in length among sites was assessed by comparing the percentages of the variance due to inter-individual and inter-site differences estimated by analysis-of-variance techniques that included adjustments for sex and age. For this analysis, the sample was restricted to those children followed for the entire period of 24 mo (88% of the enrolled sample, Table I) to permit measurement of variability within subjects using a balanced repeated-measures design. Variance components analyses [22] were based on a linear mixed-effect model. Analyses were done using SAS software, and restricted maximum likelihood was used for estimation. Age and sex were treated as fixed effects. Sites and individuals were treated as random effects. The repeated visits were also treated as random effects and represent the variability within subjects, estimated as the residual variance or random error.

The assessment of differences in length/height and the impact of individual sites on central values and selected percentiles was done by comparing each site's mean to the overall pooled mean and by comparing the effect of excluding single sites on the remaining pooled sample. Differences in length/height were expressed relative to the standard deviation (SD) of the all-site pooled sample, i.e. differences between individual site means and the pooled mean were divided by the pooled SD. These values are referred to as "standardized site effects". A similar approach was used when comparing the mean and selected percentiles calculated by excluding single sites with the corresponding pooled values. The magnitude and consistency of differences were used to assess the impact of site heterogeneity on the overall sample. According to Cohen [23], differences of 0.2 SD units are considered small, 0.5 SD medium and 0.8 SD large. In designing the MGRS, it had been decided that pooling would be appropriate if differences were less than medium in size.

Results

Table I presents the number of children in the longitudinal and cross-sectional samples and respective site-specific parental stature.

Results of variance components analyses for children in the longitudinal sample are summarized in Table II. After accounting for sex and age, variability among sites and among individuals within sites was, respectively, approximately 3% and 70% of the total variance. Thus, the percentage of the variation due to individuals was approximately 20 times greater than that due to sites.

Tables III and IV present mean lengths and heights, respectively, of the longitudinal and cross-sectional samples when all sites were pooled and for individual sites. They also present differences between individual site means and the overall pooled mean. These differences are expressed as standardized site effects, i.e. as fractions of the pooled standard deviation. Mean lengths and heights for the longitudinal and cross-sectional samples are presented graphically in Figures 1 and 2, respectively.

Differences in length (expressed as a fraction of the pooled sample SD) across sites at the indicated ages ranged from −0.33 to +0.49, most values being below 0.2 SD units (Table III). For height, values across sites at indicated ages ranged from −0.41 to +0.46 (Table IV). Although no site accounted for all the most positive or most negative differences, Oman accounted for the most negative values in seven of the nine ages and age intervals examined, and Norway and Brazil accounted most commonly for the most positive values.

Tables V and VI present, respectively, mean, 3rd percentile and 97th percentile values for length and height at the indicated ages when all sites were pooled and indicated sites excluded. Differences between values that resulted from the exclusion of single sites and the overall pooled value were also calculated. These, too, were expressed as standardized site effects, i.e. as fractions of the overall pooled standard deviation.

For length, differences between the 50th, 3rd and 97th percentiles calculated by excluding individual sites and the corresponding overall pooled values ranged from −0.10 to +0.07, −0.07 to +0.13, and −0.25 to +0.09, respectively.

For height, values ranged from −0.09 to +0.08, −0.12 to +0.13, and −0.15 to +0.07 for the 50th, 3rd and 97th percentiles, respectively. The wider ranges were observed for values at the 3rd and 97th

Table I. Sample size and parental stature in the longitudinal and cross-sectional samples.

	All sites	Brazil	Ghana	India	Norway	Oman	USA
Longitudinal sample:							
No. of enrolled children	1743	310	329	301	300	295	208
No. followed for 24 mo (% of total enrolled)	1542 (88)	287 (93)	292 (89)	269 (89)	262 (87)	260 (88)	172 (83)
Maternal stature (cm) (mean ± SD)	161.6 ± 7.2	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 stature (cm) (mean ± SD)	175.1 ± 7.9	173.6 ± 6.9	173.0 ± 6.6	172.7 ± 6.3	182.2 ± 6.7	170.4 ± 6.4	178.9 ± 7.4
Cross-sectional sample							
No. of enrolled children:	6697	487	1406	1490	1387	1447	480
Maternal stature (cm) (mean ± SD)	161.0 ± 7.2	160.0 ± 6.2	161.9 ± 5.7	157.6 ± 5.7	167.7 ± 6.5	156.6 ± 5.4	164.3 ± 6.7
Paternal stature (cm) (mean ± SD)	173.8 ± 7.9	173.2 ± 7.0	172.6 ± 6.6	172.1 ± 6.0	181.2 ± 7.2	169.2 ± 6.4	178.0 ± 7.4

Table II. Variance components analyses for length in the longitudinal sample [a].

Variance component	Estimate	Standard error (estimate)	Proportion (%)
Var(Site)	0.22	0.139	3.4
Var(Individual within site)	4.50	0.179	70.0
Var(Error)	1.71	0.032	26.6

[a] Age and sex as fixed effects.

percentiles. At the 3rd percentile, Oman's exclusion resulted in the most positive value in six of the nine ages and age intervals that were examined. Brazil's exclusion accounted for the most negative values in six of the nine ages and age intervals examined. The same pattern was observed at the 97th percentile.

Figures 3 and 4 illustrate the impact of excluding Brazil and Oman, respectively, on the 3rd, 25th, 50th, 75th and 97th length-for-age percentiles. Figures for Ghana, India, Norway and the USA are omitted because they had the least impact on the indicated percentiles when any of these sites was excluded.

Discussion

This study is the first to compare linear growth among affluent children aged 0–5 y using data collected in different countries according to a common protocol. Two lines of reasoning support the conclusion that all six MGRS sites can be used for the purpose of constructing a single international growth standard. The first relies on evidence provided by variance components analyses and, the second, on examining differences between individual site values and values derived from pooling all sites.

Variance components analyses demonstrated that variability in growth was due overwhelmingly to differences among individuals (70% of the total

Table III. Pooled and individual site sample sizes (*n*), means and standard deviations (SD) for length (cm).

Age	Sample	*n*	Mean (cm)	SD	Standardized site effects[a]
Birth	Pooled	1742	49.55	1.91	0.00
	Brazil	309	49.61	1.89	0.03
	Ghana	329	49.45	1.92	−0.05
	India	301	48.99	1.79	−0.29
	Norway	300	50.40	1.86	0.45
	Oman	295	49.18	1.72	−0.20
	USA	208	49.74	1.96	0.10
6 mo	Pooled	1648	66.72	2.35	0.00
	Brazil	296	66.75	2.35	0.01
	Ghana	306	66.57	2.29	−0.06
	India	287	66.60	2.28	−0.05
	Norway	286	67.88	2.37	0.49
	Oman	274	66.07	2.04	−0.27
	USA	199	66.30	2.39	−0.18
12 mo	Pooled	1594	75.02	2.62	0.00
	Brazil	290	75.39	2.69	0.14
	Ghana	301	75.16	2.69	0.05
	India	279	74.96	2.53	−0.02
	Norway	272	75.47	2.55	0.17
	Oman	265	74.43	2.41	−0.22
	USA	187	74.47	2.73	−0.21
18 mo	Pooled	1535	81.76	2.90	0.00
	Brazil	285	82.40	2.97	0.22
	Ghana	293	81.95	2.84	0.06
	India	268	81.50	2.86	−0.09
	Norway	255	82.06	2.77	0.10
	Oman	259	80.87	2.73	−0.31
	USA	175	81.70	3.01	−0.02
24 mo	Pooled	1524	87.40	3.18	0.00
	Brazil	280	88.35	3.17	0.30
	Ghana	289	87.48	3.04	0.03
	India	269	87.00	3.15	−0.13
	Norway	257	87.75	3.06	0.11
	Oman	260	86.36	3.08	−0.33
	USA	169	87.38	3.33	−0.01

[a] Standardized site effects are the differences between the indicated site means and the corresponding pooled (all sites) mean divided by the pooled standard deviation.

Table IV. Pooled and individual site sample sizes (*n*), means and standard deviations (SD) for height (cm).

Age	Sample	*n*	Mean (cm)	SD	Standardized site effects[a]
24–26 mo	Pooled	484	87.36	3.54	0.00
	Brazil	85	88.89	2.95	0.43
	Ghana	78	87.06	3.14	−0.08
	India	98	87.03	4.03	−0.09
	Norway	135	87.31	3.39	−0.01
	Oman	88	86.57	3.70	−0.22
	USA[b]	0			
36–38 mo	Pooled	502	96.26	4.04	0.00
	Brazil	91	97.91	4.04	0.41
	Ghana	85	96.34	3.95	0.02
	India	86	95.41	4.34	−0.21
	Norway	70	96.65	3.56	0.10
	Oman	83	95.26	3.84	−0.25
	USA	87	95.94	3.88	−0.08
48–50 mo	Pooled	478	103.52	4.23	0.00
	Brazil	71	104.87	4.84	0.32
	Ghana	94	104.29	4.56	0.18
	India	76	103.31	3.82	−0.05
	Norway	70	103.59	3.66	0.02
	Oman	80	101.78	4.31	−0.41
	USA	87	103.29	3.50	−0.05
60–62 mo	Pooled	465	110.32	4.86	0.00
	Brazil	91	111.15	4.98	0.17
	Ghana	76	112.55	6.00	0.46
	India	70	108.78	3.64	−0.32
	Norway	70	110.64	4.16	0.07
	Oman	73	109.00	4.07	−0.27
	USA	85	109.55	4.84	−0.16

[a] Standardized site effects are the differences between the indicated site means and the corresponding pooled (all sites) mean divided by the pooled standard deviation.

[b] The USA site did not enrol children in this age group for the cross-sectional study because the majority of that age cohort was participating in the longitudinal study.

variance) and only minimally to differences among sites (3% of the total variance). Thus, the percentage of the variability in length due to inter-individual differences was 20-fold greater than that due to differences among sites. Results from these analyses are consistent with genomic comparisons among

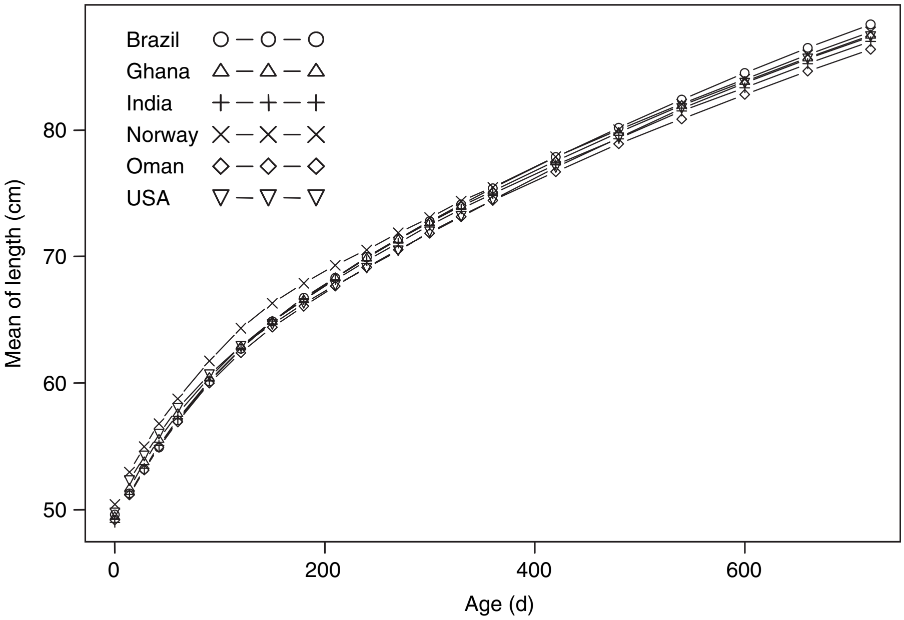

Figure 1. Mean length (cm) from birth through 2 y for each of the six sites.

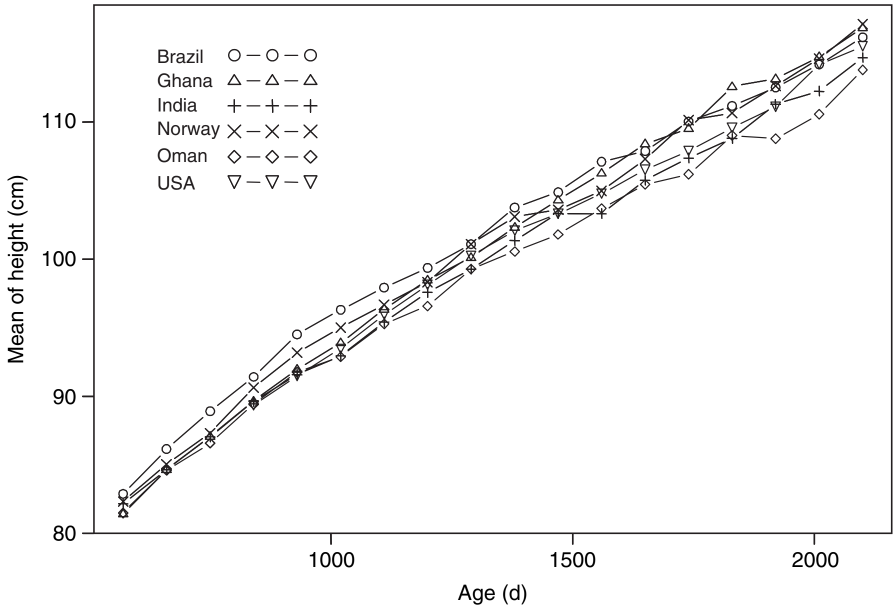

Figure 2. Mean height (cm) from 2 to 5 y of age for each of the six sites.

diverse continental groups reporting a high degree of inter-population homogeneity [24,25]. Current estimates suggest that 85 to 90% of total genetic variability resides within populations, whereas only 10% to 15% resides among populations [25]. Thus, it is unlikely that traits such as stature, which are continuous and multigenic, will differ significantly on the basis of genetics alone among large, non-isolated population groups [26]. The relatively small differences in child growth among sites, despite differences in parental stature, might decrease further in future studies. For example, the observed tendency towards smaller child size in Oman may be attributable to the shorter heights of mothers since maternal height influences birthweight and thus postnatal growth. Health conditions in Oman have improved in recent decades, and it is likely that the secular trend in adult stature will be sustained with continued economic development. Indeed, it took European populations several generations of prosperity to overcome the dire poverty and poor health that existed prior to the industrial revolution to reach their current stature [10,27].

The second set of analyses evaluated inter-site differences in length/height and the impact on selected percentiles of omitting individual sites. Ghana and the USA tended to coincide most closely with the total pool's central tendencies and distribution. Omani and, to a lesser extent, Indian children were represented commonly at lower values, and Brazilian and Norwegian children were represented commonly at higher values. Inter-site differences, however, were relatively small. For the five ages examined in the longitudinal sample and the four age intervals examined in the cross-sectional sample, no site mean deviated by an absolute amount equal to or greater than 0.5 SD of the corresponding overall sample mean. Of 54 values examined, only 20 were above 0.2 SD units, a difference considered to be small by Cohen [23], and of these only 10 were above 0.3 SD units.

The impact of differences among sites on outer and intermediate percentiles was minimal. The percentile curves depicting length from birth to 2 y for the pooled sample are nearly indistinguishable from those that result when particular sites are excluded, as illustrated by Figures 3 and 4. These figures show the impact on various percentiles of excluding the two sites with the most divergent linear growth.

Among the most salient alternatives to using all sites for the purpose of developing a single international standard is to exclude a site or sites and/or adjust for other available measurements, e.g. maternal and/or paternal stature. The former would further reduce inter-site variability and regional representation and the latter inter-individual variability. Considering that the standard will be promoted for use worldwide, neither option is compelling technically or from a policy point of view.

Differences among sites were not consistent across the ages examined. This likely reflects relatively small age-specific sample sizes at each site, residual secular trends among sites, and possibly true inter-ethnic differences and inter-site differences in the implementation of the study protocol, despite the standardization efforts described elsewhere [20]. Most importantly, however, observed inconsistencies are relatively minor and are likely of little, if any, practical and/or clinical importance. Furthermore, the

Table V. Pooled and individual site exclusion sample sizes (*n*), means (P50), standard deviations (SD), 3rd percentiles (P3) and 97th percentiles (P97) for length (cm).

Age	Sample	*n*	Mean	SD	SSE P50 (SDs)[a]	P3	SSE P3 (SDs)[a]	P97	SSE P97 (SDs)[a]
Birth	Pooled	1742	49.55	1.91	0.00	46.10	0.00	53.14	0.00
	Excluding Brazil	1433	49.54	1.91	−0.01	46.10	0.00	53.15	0.01
	Excluding Ghana	1413	49.57	1.90	0.01	46.10	0.00	53.15	0.01
	Excluding India	1441	49.67	1.91	0.06	46.20	0.05	53.20	0.03
	Excluding Norway	1442	49.37	1.87	−0.09	46.01	−0.05	53.04	−0.05
	Excluding Oman	1447	49.63	1.93	0.04	46.10	0.00	53.15	0.01
	Excluding USA	1534	49.52	1.90	−0.01	46.15	0.03	53.05	−0.05
6 mo	Pooled	1648	66.72	2.35	0.00	62.32	0.00	71.25	0.00
	Excluding Brazil	1352	66.71	2.36	0.00	62.23	−0.04	71.20	−0.02
	Excluding Ghana	1342	66.75	2.37	0.01	62.36	0.02	71.25	0.00
	Excluding India	1361	66.75	2.37	0.01	62.25	−0.03	71.25	0.00
	Excluding Norway	1362	66.47	2.28	−0.10	62.19	−0.05	70.65	−0.25
	Excluding Oman	1374	66.85	2.39	0.05	62.45	0.05	71.47	0.09
	Excluding USA	1449	66.78	2.34	0.02	62.37	0.02	71.30	0.02
12 mo	Pooled	1594	75.02	2.62	0.00	70.24	0.00	79.92	0.00
	Excluding Brazil	1304	74.94	2.60	−0.03	70.05	−0.07	79.75	−0.07
	Excluding Ghana	1293	74.99	2.61	−0.01	70.25	0.00	80.05	0.05
	Excluding India	1315	75.03	2.64	0.00	70.07	−0.06	79.90	−0.01
	Excluding Norway	1322	74.93	2.63	−0.04	70.23	0.00	79.80	−0.05
	Excluding Oman	1329	75.14	2.65	0.04	70.25	0.00	80.16	0.09
	Excluding USA	1407	75.09	2.60	0.03	70.25	0.00	80.09	0.06
18 mo	Pooled	1535	81.76	2.90	0.00	76.30	0.00	87.25	0.00
	Excluding Brazil	1250	81.62	2.86	−0.05	76.12	−0.06	86.95	−0.10
	Excluding Ghana	1242	81.72	2.91	−0.01	76.30	0.00	87.25	0.00
	Excluding India	1267	81.82	2.90	0.02	76.45	0.05	87.25	0.00
	Excluding Norway	1280	81.70	2.92	−0.02	76.17	−0.05	87.25	0.00
	Excluding Oman	1276	81.94	2.90	0.06	76.55	0.09	87.39	0.05
	Excluding USA	1360	81.77	2.88	0.00	76.30	0.00	87.21	−0.01
24 mo	Pooled	1524	87.40	3.18	0.00	81.18	0.00	93.50	0.00
	Excluding Brazil	1244	87.19	3.15	−0.07	81.06	−0.04	93.25	−0.08
	Excluding Ghana	1235	87.38	3.22	−0.01	81.10	−0.03	93.50	0.00
	Excluding India	1255	87.48	3.19	0.03	81.20	0.00	93.52	0.01
	Excluding Norway	1267	87.33	3.20	−0.02	81.10	−0.03	93.50	0.00
	Excluding Oman	1264	87.61	3.16	0.07	81.60	0.13	93.60	0.03
	Excluding USA	1355	87.40	3.17	0.00	81.23	0.01	93.47	−0.01

[a] Standardized site effects (SSE) are the differences between the indicated site means and the corresponding pooled (all sites) mean divided by the pooled standard deviation.

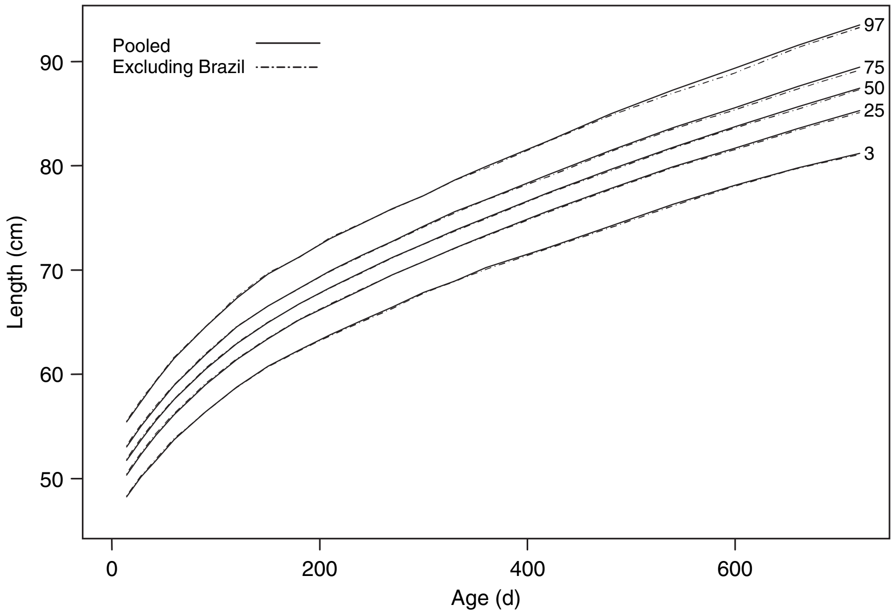

Figure 3. Length (cm) at selected percentiles for the pooled sample (solid line) and the sample following the exclusion of Brazil (dashed lines) from birth to 730 d.

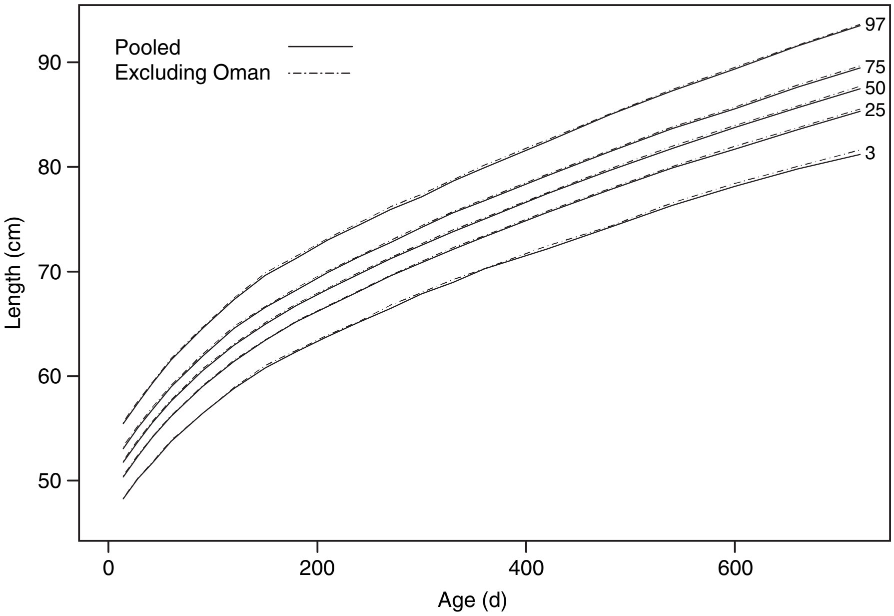

Figure 4. Length (cm) at selected percentiles for the pooled sample (solid line) and the sample following the exclusion of Oman (dashed lines) from birth to 730 d.

alternatives seem unworkable given existing ethnic diversity within countries and the evolution towards increasingly multiracial societies in the Americas and Europe as elsewhere in the world. Neither is it evident how one would adjust for children of mixed ethnicities.

Table VI. Pooled and individual site exclusion sample sizes (*n*), means (P50), standard deviations (SD), 3rd percentiles (P3) and 97th percentiles (P97) for height (cm).

Age	Sample	*n*	Mean	SD	SSE P50 (SDs) [a]	P3	SSE P3 (SDs) [a]	P97	SSE P97 (SDs) [a]
24–26 mo	Pooled	484	87.36	3.54	0.00	84.80	0.00	89.84	0.00
	Excluding Brazil	399	87.03	3.58	−0.09	84.38	−0.12	89.30	−0.15
	Excluding Ghana	406	87.41	3.62	0.02	84.60	−0.06	89.95	0.03
	Excluding India	386	87.44	3.41	0.02	84.98	0.05	90.07	0.06
	Excluding Norway	349	87.37	3.61	0.01	84.79	0.00	89.75	−0.02
	Excluding Oman	396	87.53	3.49	0.05	85.26	0.13	90.05	0.06
	Excluding USA	484	87.36	3.54	0.00	84.80	0.00	89.84	0.00
36–38 mo	Pooled	502	96.26	4.04	0.00	93.47	0.00	98.97	0.00
	Excluding Brazil	411	95.90	3.95	−0.09	93.06	−0.10	98.68	−0.07
	Excluding Ghana	417	96.25	4.06	0.00	93.45	0.00	99.06	0.02
	Excluding India	416	96.44	3.96	0.04	93.75	0.07	99.08	0.03
	Excluding Norway	432	96.20	4.11	−0.02	93.36	−0.03	98.93	−0.01
	Excluding Oman	419	96.46	4.05	0.05	93.87	0.10	99.08	0.03
	Excluding USA	415	96.33	4.07	0.02	93.56	0.02	99.05	0.02
48–50 mo	Pooled	478	103.52	4.23	0.00	100.68	0.00	106.26	0.00
	Excluding Brazil	407	103.28	4.08	−0.06	100.45	−0.05	106.18	−0.02
	Excluding Ghana	384	103.33	4.13	−0.04	100.56	−0.03	105.74	−0.12
	Excluding India	402	103.55	4.31	0.01	100.75	0.02	106.26	0.00
	Excluding Norway	408	103.50	4.33	0.00	100.56	−0.03	106.27	0.00
	Excluding Oman	398	103.87	4.14	0.08	101.18	0.12	106.50	0.06
	Excluding USA	391	103.57	4.38	0.01	100.53	−0.04	106.38	0.03
60–62 mo	Pooled	465	110.32	4.86	0.00	107.37	0.00	112.80	0.00
	Excluding Brazil	374	110.11	4.82	−0.04	107.04	−0.07	112.68	−0.02
	Excluding Ghana	389	109.88	4.49	−0.09	106.87	−0.10	112.32	−0.10
	Excluding India	395	110.59	5.01	0.06	107.49	0.03	113.18	0.08
	Excluding Norway	395	110.26	4.98	−0.01	107.03	−0.07	112.91	0.02
	Excluding Oman	392	110.56	4.97	0.05	107.49	0.03	113.14	0.07
	Excluding USA	380	110.49	4.86	0.04	107.51	0.03	113.06	0.05

[a] Standardized site effects (SSE) are the differences between the indicated site means and the corresponding pooled (all sites) mean divided by the pooled standard deviation.

In conclusion, these analyses document the strong similarity in linear growth from birth to 5 y in major ethnic groups living under relatively affluent conditions. They also support the inclusion of all six MGRS sites for the purpose of constructing a single international standard. The limitations of applying a prescriptive approach to free-living subjects and those imposed by a community-based sampling strategy likely preclude an error-free description of ideal growth patterns. Yet, despite those limitations and the marked differences among study sites in population and environmental characteristics, the similarity in linear growth among sites is striking. Most importantly, a single international standard for assessing the growth of all children embodies the very powerful message that when health and key environmental needs are met, the world's children grow very similarly.

The growth curves based on the pooled MGRS data for length/height-for-age, weight-for-age, weight-for-length/height and body mass index-for-age are presented in a companion paper in this supplement [28]. They represent the best description of physiological growth and should be applied to all children everywhere, regardless of ethnicity, socio-economic status and type of feeding.

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