

Length and height percentiles for children in the South-East Asian Nutrition Surveys (SEANUTS)

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Submitted 30 January 2015: Final revision received 30 September 2015: Accepted 20 October 2015: First published online 24 November 2015

Abstract

Objective: Health and nutritional information for many countries in the South-East Asian region is either lacking or no longer up to date. The present study aimed to calculate length/height percentile values for the South-East Asian Nutrition Survey (SEANUTS) populations aged 0–5–12 years, examine the appropriateness of pooling SEANUTS data for calculating common length/height percentile values for all SEANUTS countries and whether these values differ from the WHO growth references.

Design: Data on length/height-for-age percentile values were collected. The LMS method was used for calculating smoothed percentile values. Standardized site effects (SSE) were used for identifying large or unacceptable differences (i.e. $|SSE| > 0.5$) between the pooled SEANUTS sample (including all countries) and the remaining pooled SEANUTS samples (including three countries) after weighting sample sizes and excluding one single country each time, as well as with WHO growth references.

Setting: Malaysia, Thailand, Vietnam and Indonesia.

Subjects: Data from 14 202 eligible children were used.

Results: From pair-wise comparisons of percentile values between the pooled SEANUTS sample and the remaining pooled SEANUTS samples, the vast majority of differences were acceptable (i.e. $|SSE| \leq 0.5$). In contrast, pair-wise comparisons of percentile values between the pooled SEANUTS sample and WHO revealed large differences.

Conclusions: The current study calculated length/height percentile values for South East Asian children aged 0–5–12 years and supported the appropriateness of using pooled SEANUTS length/height percentile values for assessing children's growth instead of country-specific ones. Pooled SEANUTS percentile values were found to differ from the WHO growth references and therefore this should be kept in mind when using WHO growth curves to assess length/height in these populations.

Keywords
Nutrition
Survey
Length/height
Percentiles
Children
SEANUTS

The economic transition due to rapid industrialization observed over the last decades in South-East Asian countries has coincided with marked changes in dietary habits and lifestyle patterns that may have a significant impact on several health indices in these populations^(1–4). Because of these lifestyle changes, growth and physical development in infants, children and adolescents can be influenced and this is reflected mainly in changes recorded over time in certain anthropometric indicators, namely body weight,

stature (or recumbent length in infants) and BMI. In this context, according to data from the WHO^(5,6), the decreasing trend in the prevalence of stunting (by 43.4 million) and underweight (by 35.6 million) and the increasing prevalence of overweight and obesity (by 4.4 million) observed over the last two decades among children in South-East Asia (including Thailand, Indonesia and Malaysia) provide a strong indication of this impact.

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The assessment of growth, health and nutritional status in infants, children and adolescents relies mainly on the use of growth reference percentile values and standards. In 2006, WHO published new growth standards for infants and children from birth to 5 years of age⁽⁷⁾. For the development of these new growth standards the WHO Multicentre Growth Reference Study (MGRS) was conducted between 1997 and 2003 to collect anthropometric data in Brazil, Ghana, India, Norway, Oman and the USA. Furthermore, in 2007 the WHO released growth standards for children and adolescents from 5 to 19 years of age, which were based on the reconstruction of the 1977 National Center for Health Statistics/WHO growth reference values⁽⁸⁾. However, certain studies report deviations of mean anthropometric indices compared with the WHO reference in healthy Asian child populations^(9,10). Relevant discrepancies derived from comparisons with the WHO growth reference values have also been reported for more prosperous South Asian (Indian) children living in the Netherlands^(11,12), thus raising questions regarding the general applicability of the WHO reference as an international growth standard. Although WHO growth references are intended for international use, variations in the genetic backgrounds and environmental influences among different populations worldwide^(13–16) may generate the need for additional country/region-specific growth reference values.

Although many countries in the South-East Asian region had conducted surveys in the past, it was believed that health and nutritional information, especially in older infants and children, was lacking or no longer up to date. With this background, the South-East Asian Nutrition Survey (SEANUTS) was initiated in 2010. SEANUTS was conducted in large country-representative samples of 0.5- to 12-year-old infants and children in Indonesia, Malaysia, Thailand and Vietnam. The study aimed to provide insights into the nutritional status, growth, food intake, physical activity and health of the children living in South-East Asia⁽¹⁷⁾.

The objectives of the present study were to: (i) derive length/height percentile values from the SEANUTS population, using equivalent exclusion criteria and following a similar methodological approach as WHO in developing its growth references⁽¹⁸⁾; (ii) examine the appropriateness of pooling SEANUTS data for developing common length/height percentile values for all SEANUTS countries or using country-specific ones, instead; and (iii) examine whether the pooled SEANUTS length/height percentile values are different from the reference values provided by WHO.

Materials and methods

Sampling

The sampling procedures followed in each one of the four SEANUTS countries are described in detail elsewhere^(17,19–22). In brief, both Indonesia and Thailand used population-based sampling approaches, whereas Malaysia

and Vietnam performed their sampling in nurseries, kindergartens and primary schools. More specifically the surveys conducted in Indonesia and Thailand were household-based, thus resulting in also recruiting children who were not necessarily enrolled in nurseries, kindergartens or primary schools. In addition, the surveys conducted in Malaysia and Vietnam were school-based, i.e. using nurseries, kindergartens and primary schools as 'entry points' for recruiting children and also approaching and collecting data from their parents. Furthermore, Indonesia, Thailand and Vietnam used a multistage cluster sampling approach, while Malaysia used a stratified random sampling approach. Urban and rural areas were taken as strata and the various (sub) regions per country as clustering units. The principal clustering unit was the demographic unit with the highest number of inhabitants. Weight factor calculation was done on the basis of the number of boys and girls per age group defined per regional unit as representative to the total number of children in the next demographic unit and finally to national level. This was done according to the demographic information per country available during the last national census (i.e. in all countries, that of 2010) obtained from the respective National Statistics Centres. The sampling procedures resulted in representative samples of boys and girls from both urban and rural areas in each one of the four SEANUTS countries and consequently in the recruitment of a total number of 16744 infants and children aged 0–12 years. These children were considered apparently healthy since they did not exhibit any sign of physical, clinical mental or clinical genetic disorders at the time of recruitment and were capable of participating in the study. Exclusion criterion for participation was age <6 months and >12 years (except for Vietnam that used 11 years as an upper age cut-off, since this is the upper age limit for attending primary school in the country). Further to the representativeness achieved at a country level, the study population could also be considered as representative at a regional level, since it reflected the distribution of children in the four SEANUTS countries. In this context, the higher number of study participants from Indonesia reflected the larger population of Indonesian children aged 0–14 years, according to demographic data derived from the national census of 2010 as well as from the World Bank for the years of 2010 and 2011⁽²³⁾.

Power analysis

The number of participants included in each of the four countries was based on the potential occurrence of underweight (9.0–18.4%). More information on the algorithm used for the power analysis and sample size calculation in the present study is provided elsewhere^(17,19–22).

Data collection

The methodological procedures followed for data collection were standardized when feasible, thus facilitating

comparison of results among countries. The present study is registered in the Netherlands Trial Registry as NTR2462.

Each of the countries used mobile field teams to visit the regions randomly selected to be included in the study. Each team consisted of researchers with knowledge of nutrition and/or biomedical analysis. All research team members were centrally trained on the objectives of the study, sampling procedures, anthropometric measurements, clinical examinations, interviewing techniques, sequence of questionnaires and their variables, field management and, at a later stage, data entry and 'cleaning'.

Length and height measurements

Height was measured using a stadiometer or microtoise to the nearest 0.1 cm. For height measurements, children were measured standing straight and barefooted, with their heels (together), shoulder, back and buttocks touching the wall and head aligned to the Frankfurt horizontal plane. In children aged below 2 years, recumbent length was measured to the nearest 0.1 cm using a length board.

Sociodemographic background and general health status

Sociodemographic data, including the level of parental education and income, as well as health status data were collected via a set of questionnaires that were filled in with information provided by parents and children. All questionnaires were interviewer- or self- (parents) administered. For children aged 6 months to 9 years the interviews were conducted with their parents or caregivers, while for children aged 10 years and older the interviews were conducted with both children and their parents.

Data processing and exclusion criteria

Following the collection of data, data entry was done using specially developed programs (Indonesia and Thailand), Epi Info (Malaysia) and EpiData 3.1 (Vietnam).

In addition, Excel files with a fixed format were used by all countries for the final overview of data. At least 10% of data had a double entry made by different persons to check the accuracy of data entry. Excel files, statistical data files and other information related to the study were uploaded to a specially secured SEANUTS website on a regular basis where all data were accessible for the project team and per country for the specific research teams.

At regular time intervals, these data tables were cleaned and checked for obvious outliers, typing errors and missing data using specific tools within STATA version 12, PASW Statistics version 18 and Excel. Accordingly, missing values have been coded and are not included in the final evaluation. Outliers were checked for potential effects on the various population-based results and discussed with the representatives per country. The various descriptive values are all weighted for population size/distribution, and mean values have been tested for differences after correction for age and/or area of residence where appropriate.

In order to make SEANUTS data as comparable as possible to the anthropometric indices collected in the MGRS, the exclusion/inclusion criteria applied in the latter study (namely 'children's health status', 'maternal educational level' and 'family income') were also used (up to the extent this was applicable) in the case of SEANUTS (Table 1). Regarding the exclusion criteria of 'children's health status' and 'maternal educational level', these were used to identify eligible children in all participating countries. Concerning 'family income', this was not used as an exclusion criterion only in the case of Vietnam due to non-availability of these data for approximately 31% of the population under study. In addition, in the case of Indonesia, instead of income a proxy socio-economic status (SES) score was used (i.e. combining data on household expenditures for food and non-food items, housing condition and household valuable goods). This is

Table 1 Exclusion criteria applied to identify eligible subjects in the total SEANUTS sample and in each individual country

Exclusion criterion	Description
1. Children's health status	Children from Malaysia, Thailand and Vietnam (data were available for children up to the age of 6 years) having any of the following diseases were excluded: heart disease, diabetes, seizures/epilepsy, physical handicap and genetic disease Children from Indonesia having any of the following disease were excluded: typhoid fever, malaria, tuberculosis, haemorrhagic fever or any other kind of serious fever within the last 12 months
2. Maternal education	Children with illiterate mothers (i.e. mothers with 'no schooling') were excluded
3. Family income	Thailand: children whose families had a monthly household income below 2422 Baht per family member were excluded Malaysia: children whose families had a monthly household income below 720 RM were excluded Indonesia: while in the other three SEANUTS countries data were collected on income, a proxy of family income was used based on housing condition and valuable goods owned by the family, similar to the methods also used by the Indonesian Central Bureau of Statistics. Specifically, a continuous SES score was calculated by scoring the variables of housing condition and goods and by summing them up. The total SES score was divided into deciles (i.e. 1–10) and children in the first decile (i.e. the poorest) were excluded Vietnam: The 'family income' criterion was not used in the case of Vietnam, since this information was not available for ~31% of the population under study

SEANUTS, South-East Asian Nutrition Survey; SES, socio-economic status.

a common approach for assessing SES in Indonesia, dictated by the Indonesian Central Bureau of Statistics⁽²⁴⁾. This is because family income is not considered to be a valid index of SES in Indonesia because there are income sources additional to the take-home salary coming from formal employment; for example, there might be also a daily or monthly income coming from occasional employment. The poverty threshold in Indonesia is set at the first decile of the SES score. In Thailand, the poverty threshold is set at 2422 Baht per family member per month as proposed by the National Economic and Social Development Board of Thailand⁽²⁵⁾. In Malaysia the poverty threshold is set at 720 RM per month according to the Malaysian Department of Statistics⁽²⁶⁾. After applying the aforementioned exclusion criteria, a final total pooled SEANUTS sample of 14 202 children with full data on length/height, age and sex was used in the current analyses (Table 2). Those children excluded (i.e. *n* 2364) were almost consistently found to have significantly lower levels of height/length per year of age in all age groups from 1 to 10 years, compared with those children who were not excluded (data not shown). This indicates that the criteria used to exclude children in the current study could be considered valid enough in identifying and thus excluding those with possible health and/or socio-economic constraints on their growth.

Statistical analysis

Smoothing methods

Cole and Green’s LMS method⁽²⁷⁾, which summarizes the distribution of data by sex and age in terms of three spline curves called L, M and S (i.e. the Box–Cox transformation power that converts data to normality and minimizes the skewness of the data set (L), the median (M) and the coefficient of variation (S)), was used to calculate percentile (P) values. More specifically, the software LMSChartMaker version 2.54 was used to extract the ‘smoothed’ percentile values at P3, P5, P50, P95 and P97 for body length/height by sex and age. As the LMSChartMaker software also provides the feature/setting of using transformed age for complex M curves that rise and fall at different age intervals, age was log-transformed in the current study to obtain a better fit during age intervals of faster or slower growth velocities. For achieving an optimal fit and determining the amount of smoothness of the curves, the number of the ‘equivalent degrees of freedom’ was used. After achieving an optimal fit, the distribution of age was rescaled back to original age. Lastly, in order to also adjust for unequal sample sizes in the four sites and avoid over-representation of Indonesia, the samples of Malaysia, Thailand and Vietnam were weighted before extracting the ‘smoothed’ length/height percentile values using a weight factor of ‘2’, thus achieving approximately equal sample sizes in all sites.

Table 2 Frequency and percentages of children excluded or included in the current analysis, based on each individual exclusion criterion as well as their combination

	Indonesia		Malaysia		Thailand		Vietnam		Total	
	<i>n</i>	%*	<i>n</i>	%*	<i>n</i>	%*	<i>n</i>	%*	<i>n</i>	%*
Total initial sample	7169	100.0	3530	100.0	3110	100.0	2757	100.0	16 566	100.0
Children's health status										
Excluded	265	3.7	56	1.6	34	1.1	11	0.4	366	2.2
Included	6904	96.3	3474	98.4	3076	98.9	2746	99.6	16 200	97.0
Maternal education										
Excluded	143	2.0	67	1.9	90	2.9	193	7.0	493	3.0
Included	7026	98.0	3463	98.1	3020	97.1	2564	93.0	16 073	97.0
Family income†										
Excluded	760	10.6	427	12.1	382	12.3	–	–	1569	9.5
Included	6409	89.4	3103	87.9	2728	87.7	2757	100.0	14 997	90.5
Combination of all three exclusion criteria										
Excluded	1069	14.9	615	17.4	476	15.3	204	7.4	2364	14.3
Included	6100	85.1	2915	82.6	2634	84.7	2553	92.6	14 202	85.7

SES, socio-economic status.

*Percentage of the total sample initially recruited.

†The ‘family income’ exclusion criterion was not applied in the case of Vietnam. A proxy ‘SES score’ criterion was used in the case of Indonesia instead of income.

Assessment of length/height differences

The current study assessed the differences in the 'smoothed' length/height percentile values by age groups in two ways: (i) between the pooled SEANUTS sample and the remaining pooled SEANUTS samples after excluding single 'sites', which refers to countries in the SEANUTS; and (ii) between WHO and the pooled SEANUTS sample. Differences in 'smoothed' length/height-for-age percentile values were expressed relative to the *SD* of the WHO and the all-sites pooled SEANUTS sample, respectively. For example, for comparing WHO with pooled SEANUTS data, the 'standardized site effects' (SSE) were calculated, indicating the differences between WHO and pooled SEANUTS percentile values divided by the WHO *SD*. As an example, the following formula was used for the calculation of the SSE for the third percentile:

$$\text{SSE (P3)} = \frac{\text{P3 (pooled SEANUTS)} - \text{P3 (WHO)}}{\text{SD (mean/P50)}}$$

The same approach was used when comparing pooled SEANUTS percentile values with the corresponding percentile values for the remaining pooled SEANUTS sample after excluding single sites. The magnitude and consistency of the observed differences, based on the calculated SSE values, were used to examine the two main objectives of the present study. In this context, absolute SSE differences of ≥ 0 to < 0.2 are considered small, ≥ 0.2 to < 0.5 are considered medium, and ≥ 0.5 are considered large⁽²⁸⁾. Similar to the approach also followed in the WHO MGRS study⁽²⁹⁾, $|\text{SSE}|$ were acceptable if these were < 0.5 .

Results

The LMS values of the length/height distributions are presented in the online supplementary material, Supplemental Table 1 for boys and girls of the pooled SEANUTS sample. The distributions of length/height in boys were not symmetrical (i.e. $L=1$) since in the ages from 1 to 9 years the values of L were higher than 1, indicating skewness to the left, while in the age groups of 0.5 and 10 to 12 years the L values were lower than 1, indicating skewness to the right. Similarly, non-symmetrical distributions were also observed for length/height in girls, since all values of L in the ages from 0.5 to 10 years were lower than 1, while in the age groups of 11 and 12 years the L values were higher than 1.

In line with the first objective of the current study (i.e. deriving growth percentile values from the SEANUTS population), Supplemental Tables 2 and 3 in the online supplementary material present the length/height-for-age percentile values (i.e. at P3, P5, P50, P95 and P97) in the age groups of 0.5 to 12 years, for boys and girls, respectively. A summary of the above data, for specific percentiles (i.e. P3, P50 and P97) and age groups for boys

and girls, is presented in Table 3. In the context of the second objective of the current study (i.e. to examine the appropriateness of using pooled SEANUTS data instead of country-specific ones), these same tables present the pair-wise comparisons of length/height-for-age percentile values between the pooled SEANUTS sample (i.e. including data from all four countries) and the remaining pooled SEANUTS samples after excluding the data from each country. Although absolute values of SSE that are higher than 0.5 indicate large (i.e. unacceptable) differences and potential inappropriateness of using pooled SEANUTS instead of country-specific data, only a few large differences were observed. More specifically, only eight large differences in length/height percentile values were observed in boys when excluding data from Indonesia. These differences were observed at the lower percentiles (i.e. P3, P5) for the age groups of 1 to 4 years (Table 3 and Supplemental Table 2). In girls, only five large differences were observed at the lower percentiles (i.e. P3, P5) for the age groups of 1.5 to 3 years when excluding data from Indonesia (Table 3 and Supplemental Table 3).

As far as the third and last objective of the current study is concerned (i.e. to examine the differences between pooled SEANUTS and WHO data), Supplemental Tables 4 and 5 (as well as Supplemental Figs 1 and 2) in the online supplementary material present for boys and girls respectively the length/height-for age percentile values (i.e. at P3, P5, P50, P95 and P97) for the age groups of 0.5 to 12 years and the SSE values for these comparisons. A summary of the above data, for specific percentiles (i.e. P3, P50 and P97) and age groups for boys and girls, is presented in Table 4. Out of a total of seventy comparisons between pooled SEANUTS and WHO data, fifty-two large differences were observed for boys and girls, respectively. The vast majority of these were negative and were observed in the lower and median percentiles (i.e. P3, P5 and P50) in almost all age groups and both sexes. In the upper percentiles (i.e. P95, P97) there were five positive large differences observed in both sexes for the age groups of 0.5 and 1 years, while all other large differences were negative and observed in the age groups of 1.5 to 9 years (Table 4 as well as Supplemental Tables 4 and 5, respectively).

Discussion

The SEANUTS study is a large-scale epidemiological survey conducted in country-representative samples of 0.5- to 12-year-old children from Indonesia, Malaysia, Thailand and Vietnam. With respect to its first objective, i.e. deriving length/height percentile values from the SEANUTS population, the present study employed certain exclusion criteria for identifying eligible children which were as similar as possible (based on data availability) to the ones used by WHO in the MGRS⁽¹⁸⁾. Following this

Table 3 Pair-wise comparisons of the median (P50), third (P3) and ninety-seventh (P97) percentile values for length/height in boys and girls between the pooled SEANUTS sample and the remaining pooled SEANUTS sample after excluding single sites

	Length/height (cm)													
	Boys							Girls						
	P50			P3		P97		P50			P3		P97	
	Mean	SD	SSE	Mean	SSE	Mean	SSE	Mean	SD	SSE	Mean	SSE	Mean	SSE
6 months														
Pooled SEANUTS	68.1	3.6	0.00	61.3	0.00	75.0	0.00	65.9	3.0	0.00	60.6	0.00	71.8	0.00
Excluding:														
Malaysia	68.2	3.7	0.04	61.4	0.03	75.2	0.05	65.7	3.0	-0.06	60.4	-0.05	71.7	-0.02
Thailand	68.2	3.7	0.01	61.5	0.05	75.4	0.12	65.9	3.0	0.01	60.6	0.03	72.0	0.09
Indonesia	67.8	2.8	-0.09	62.9	0.43	73.4	-0.43	65.4	2.5	-0.14	61.1	0.17	70.5	-0.43
Vietnam	68.0	3.7	-0.03	61.2	-0.03	75.2	0.06	65.8	3.0	-0.02	60.4	-0.06	71.7	-0.01
2 years														
Pooled SEANUTS	84.0	4.4	0.00	75.3	0.00	92.0	0.00	82.6	4.0	0.00	75.4	0.00	90.3	0.00
Excluding:														
Malaysia	84.1	4.5	0.00	74.0	-0.28	92.2	0.04	82.5	4.1	-0.02	75.1	-0.06	90.4	0.02
Thailand	83.4	4.5	-0.14	74.7	-0.12	91.6	-0.08	82.0	4.0	-0.13	74.9	-0.12	90.1	-0.06
Indonesia	85.0	3.7	0.21	78.3	0.68	92.1	0.03	83.8	3.5	0.30	77.6	0.56	90.7	0.10
Vietnam	83.8	4.5	-0.06	75.0	-0.05	91.9	-0.02	82.4	4.0	-0.05	75.0	-0.08	90.1	-0.04
4 years														
Pooled SEANUTS	99.9	5.2	0.00	89.4	0.00	109.0	0.00	98.7	5.0	0.00	89.5	0.00	108.4	0.00
Excluding:														
Malaysia	99.6	5.4	-0.06	88.6	-0.15	109.0	-0.01	98.2	5.1	-0.08	88.9	-0.12	108.2	-0.05
Thailand	99.1	5.3	-0.14	88.6	-0.16	108.6	-0.09	97.9	5.1	-0.15	88.8	-0.15	108.0	-0.08
Indonesia	101.0	4.6	0.22	92.2	0.55	109.5	0.09	99.9	4.5	0.25	91.7	0.43	108.7	0.06
Vietnam	99.6	5.2	-0.04	89.4	0.01	108.9	-0.02	98.6	5.1	-0.02	89.4	-0.03	108.4	0.00
6 years														
Pooled SEANUTS	112.6	5.8	0.00	101.1	0.00	123.0	0.00	111.4	5.8	0.00	100.7	0.00	122.7	0.00
Excluding:														
Malaysia	112.0	6.0	-0.10	100.0	-0.18	122.7	-0.04	110.9	5.9	-0.08	100.1	-0.10	122.4	-0.05
Thailand	112.2	6.0	-0.06	100.4	-0.11	122.9	0.00	110.8	6.0	-0.10	100.1	-0.11	122.6	-0.02
Indonesia	113.5	5.4	0.16	103.0	0.35	123.3	0.05	112.4	5.4	0.18	102.5	0.31	122.8	0.02
Vietnam	112.4	5.7	-0.03	101.3	0.04	122.8	-0.03	111.2	5.9	-0.02	100.6	-0.03	122.6	0.00
8 years														
Pooled SEANUTS	123.6	6.4	0.00	111.2	0.00	135.5	0.00	122.9	6.6	0.00	110.8	0.00	135.5	0.00
Excluding:														
Malaysia	122.9	6.6	-0.11	110.2	-0.15	135.2	-0.04	122.3	6.6	-0.09	110.2	-0.09	135.1	-0.06
Thailand	123.3	6.6	-0.04	110.7	-0.08	135.6	0.02	122.4	6.7	-0.07	110.2	-0.08	135.6	0.01
Indonesia	124.4	6.1	0.14	112.7	0.24	135.7	0.04	124.0	6.2	0.17	112.5	0.26	135.8	0.05
Vietnam	123.4	6.3	-0.02	111.5	0.05	135.2	-0.04	122.8	6.6	-0.01	110.6	-0.03	135.5	0.00
10 years														
Pooled SEANUTS	133.8	7.2	0.00	120.5	0.00	147.5	0.00	134.7	7.3	0.00	121.0	0.00	148.6	0.00
Excluding:														
Malaysia	132.9	7.3	-0.13	119.5	-0.14	147.1	-0.06	133.7	7.4	-0.13	120.1	-0.12	147.8	-0.10
Thailand	133.4	7.4	-0.05	119.8	-0.09	147.5	0.00	134.3	7.5	-0.06	120.4	-0.08	148.6	0.00
Indonesia	134.7	6.9	0.12	121.8	0.18	147.9	0.05	135.7	7.0	0.14	122.7	0.23	149.0	0.06
Vietnam	134.0	7.0	0.02	121.0	0.07	147.4	-0.01	134.9	7.4	0.02	120.9	-0.01	148.6	0.01

SEANUTS, SEANUTS, South-East Asian Nutrition Survey; SSE, standardized site effect (difference between the indicated site mean and the corresponding pooled SEANUTS (all sites) mean divided by the pooled SD). SSE marked in bold font correspond to values greater than 0.5 or lower than -0.5.

Table 4 Comparisons of the median (P50), third (P3) and ninety-seventh (P97) percentile values for length/height in boys and girls between WHO and pooled SEANUTS samples

	Length/height (cm)													
	Boys							Girls						
	P50			P3		P97		P50			P3		P97	
	Mean	sd	SSE	Mean	SSE	Mean	SSE	Mean	sd	SSE	Mean	SSE	Mean	SSE
6 months														
WHO	67.6	2.1	0.00	63.6	0.00	71.6	0.00	65.7	2.3	0.00	61.5	0.00	70.0	0.00
Pooled SEANUTS	68.1	3.6	0.22	61.3	-1.07	5.0	1.57	65.9	3.0	0.05	60.6	-0.42	71.8	0.77
2 years														
WHO	87.8	3.1	0.00	82.1	0.00	93.6	0.00	86.4	3.2	0.00	80.3	0.00	92.5	0.00
Pooled SEANUTS	84.0	4.4	-1.24	75.3	-2.24	92.0	-0.53	82.6	4.0	-1.20	75.4	-1.54	90.3	-0.68
4 years														
WHO	103.3	4.2	0.00	95.4	0.00	111.2	0.00	102.7	4.3	0.00	94.6	0.00	110.8	0.00
Pooled SEANUTS	99.9	5.2	-0.83	89.4	-1.43	109.0	-0.52	98.7	5.0	-0.95	89.5	-1.18	108.4	-0.56
6 years														
WHO	116.0	4.9	0.00	106.7	0.00	125.2	0.00	115.1	5.1	0.00	105.5	0.00	124.8	0.00
Pooled SEANUTS	112.6	5.8	-0.69	101.1	-1.15	123.0	-0.45	111.4	5.8	-0.74	100.7	-0.94	122.7	-0.42
8 years														
WHO	127.3	5.7	0.00	116.6	0.00	137.9	0.00	126.6	5.8	0.00	115.7	0.00	137.5	0.00
Pooled SEANUTS	123.6	6.4	-0.66	111.2	-0.96	135.5	-0.43	122.9	6.6	-0.64	110.8	-0.85	135.5	-0.34
10 years														
WHO	137.8	6.4	0.00	125.8	0.00	149.8	0.00	138.6	6.4	0.00	126.6	0.00	150.7	0.00
Pooled SEANUTS	133.8	7.2	-0.62	120.5	-0.83	147.5	-0.36	134.7	7.3	-0.61	121.0	-0.88	148.6	-0.34

SEANUTS, SEANUTS, South-East Asian Nutrition Survey; SSE, standardized site effect (difference between WHO mean and the corresponding pooled SEANUTS mean divided by the WHO sd). SSE marked in bold font correspond to values greater than 0.5 or lower than -0.5.

procedure a total sample of 14 202 eligible infants and children were included in the present analyses for deriving the length/height percentile values from SEANUTS. Considering the age range of children in SEANUTS (i.e. 0.5 to 12 years old), this final sample size is comparable to the sample sizes of the MGRS (i.e. 8440 infants and children 0–6 years old)⁽⁷⁾ and the National Center for Health Statistics (i.e. 22 917 children and adolescents 5–19 years old)⁽⁸⁾ used to construct the current WHO growth references.

Regarding the second objective, i.e. examining whether it is more appropriate to use the pooled SEANUTS data for calculating common length/height percentile values for all SEANUTS countries instead of country-specific ones, the few large differences observed among individual SEANUTS countries and the pooled SEANUTS sample are supporting the appropriateness of using pooled SEANUTS data. These differences were observed in the lower percentiles (i.e. P3 and P5), for the age groups of 1 to 4 years and primarily when excluding Indonesia from the total sample, indicating that the Indonesian sample tended to coincide most closely to the pooled SEANUTS sample percentile values. In addition, the consistent positive SSE values observed indicate that children from Indonesia below the age of 5 years have lower length/height values at P3 and P5 compared with the other three countries. Nevertheless, out of a total number of 280 comparisons (i.e. fourteen age time points, five percentiles and four SEANUTS countries) conducted for each sex, the vast majority of inter-site differences were relatively small indicating comparable length/height percentile values between pooled SEANUTS and individual countries (see Supplemental Tables 2 and 3 in the online supplementary material).

The procedures followed by the present study to examine its objectives are similar to those previously followed by WHO in the MGRS⁽²⁹⁾. The findings of the present study are in line with those reported by WHO when assessing differences in body length/height percentile values among the different participating populations/countries⁽²⁹⁾. In their article, the WHO MGRS Group reported that the variability in length/height percentile values was due primarily to inter-individual differences rather than to differences among sites. Since approximately 90% of the total genetic variability resides within populations while only 10–15% is across populations⁽³⁰⁾, the WHO authors further argue that it is unlikely for growth indices, such as stature, to differ significantly among large non-isolated population groups⁽³¹⁾ and that the relatively small differences among sites observed in the MGRS was rather expected and might decrease further in future studies. Up to a certain degree the findings derived from SEANUTS data in the current study are supportive to the aforementioned argument made by the WHO MGRS Group, as the vast majority of inter-site differences in length/height percentile values were quite small.

The third objective of the present study was to examine whether the length/height percentile values developed from the pooled SEANUTS data were different from the corresponding ones provided by WHO⁽⁷⁾. The results derived from these comparisons between pooled SEANUTS and WHO length/height percentile values show that the data differ. Specifically, these comparisons revealed that length/height values were consistently lower in the pooled SEANUTS sample compared with WHO in almost all ages and percentiles in both sexes. The differences observed in the current study between WHO and SEANUTS percentile values should be kept in mind when using WHO growth curves to assess length/height in these South-East Asian populations. The findings of the current study could reflect actual differences at a population level between the pooled SEANUTS and WHO length/height percentile values. Following this reasoning, the lower (compared with WHO) length/height values that were almost consistently observed in both sexes, all ages and percentiles examined in the current study are in line with the available literature reporting lower stature for South Asian populations compared with populations on other continents⁽³²⁾ and indicating that shorter length/height is very likely to be the actual phenotype for South Asian populations⁽¹²⁾.

However, the large differences between pooled SEANUTS and WHO data for almost all ages and percentiles could also be due to certain limitations of the present study such as the ones listed below. First, although the majority of exclusion criteria applied in the present study were similar to those used by WHO in the MGRS, the application of all exclusion criteria was not feasible. Specifically, although the rates of exclusive breast-feeding (up to 6 months of age) have been reported to range from 15.1% in Thailand to 41.5% in Indonesia^(14,33), the 'breastfeeding criterion' could not be used since this information was available for only a small sub-sample of the total SEANUTS sample. Non-availability of data also applied for other potential perinatal constraints on growth (e.g. premature birth and low birth weight), since these data were either not collected in the four SEANUTS countries or collected retrospectively for only a small sub-sample of younger (i.e. <2 years old) children. Regarding limitations in applying the rest of the exclusion criteria, the 'family income' criterion was not used in the case of Vietnam as these data were not available for approximately 31% of the total sample. However, in all age groups mean length/height values were consistently found to be lower in children excluded from the current analyses (i.e. *n* 2364) compared with children included in the analyses (i.e. *n* 14 202; data not shown). This probably indicates that the exclusion criteria applied in the current study were valid enough in identifying children with health and/or socio-economic constraints on their growth. Further to the limitations stemming from the application of the 'exclusion criteria', the school-based sampling in

Malaysia and Vietnam could probably have resulted in non-inclusion of eligible children who were not enrolled in nurseries, kindergartens and primary schools. Furthermore, non-availability of blood samples/data for the total SEANUTS population could be considered another limitation, since children with anaemia and/or other micronutrient deficiencies negatively affecting growth could not be detected and consequently excluded from the current analyses. Lastly, despite the existence and use by other studies of alternative statistical methods to examine differences in percentile values^(11,12), the current study used SSE, thus following the same approach as WHO in assessing differences in linear growth in the MGRS⁽²⁹⁾.

Conclusion

In conclusion, the current study developed length/height percentile values for infants and children aged 0.5 to 12 years from four South-East Asian countries and was supportive of the appropriateness of using pooled SEANUTS percentile values for assessing children's length/height in all four countries. The length/height percentile values developed in the present study were found to differ from the ones provided by WHO. Additional research initiatives should be considered for proposing appropriate length/height cut-off points for assessing linear growth in South-East Asian children and adolescents.

Acknowledgements

Acknowledgements: The authors are indebted to the research team members of the SEANUTS Study Group, as well as to the parents/carers, infants and children for their willingness to participate in the study. The SEANUTS Study Group comprises the following. Thailand: Nipa Rojroongwasinkul, Atitada Boonpradern, Pattanee Winichagoon, Petcharat Kunaphan, Uruwan Yamborisut, Wanphen Wimonpeerapattana, Sayamon Senaprom, Kallaya Kijboonchoo, Wiyada Thasanasuwan, Weerachat Srichan, Kusol Soonthornhdhada, Sasiumphai Purttiponthanee. Vietnam: Khanh Le Nguyen Bao, Chinh Nguyen Huu, Hop Le Thi, Truong Nguyen Hong, Van Anh Nguyen Do, Do Tran Thanh, Nga Tran Thuy, Nhung Bui Thi, Dzung Nguyen Dinh, Tuoc Bui Van, Khang Nguyen Van, Dzung Nguyen Viet, Luan Nguyen Viet, Ha Nguyen Thu Ha, Xuyen Hoang Thi, Long Nguyen Van, Hai Tran Thi, Long Pham Si, Huong Nguyen Thi, Ngan Nguyen Thi, Thao Le Thanh, Kieu Dau Thi, Thang Dinh Tat, Mai Nguyen Thi Tuyet. Indonesia: Sandjaja, Basuki Budiman, Moesijanti Soekatri, Heryudarini Harahap, Fitrah Ernawati, Yekti Widodo, Edith Sumedi, Nurmeida S. Syarief, Rustan Effendi, Gustina Sofia, Minarto, Hidayat Syarief. Malaysia: Poh Bee Koon, Norimah A Karim, Ruzita A Talib, Siti Balkis Budin, Alvin Ng Lai Oon,

Siti Haslinda Mohd Din, Wong Jyh Eiin, Mohd Ismail Noor, Rahman Jamal, Nor Azmi Kamaruddin, Nik Shanita Safi, Chin Yit Siew, Wee Bee Suan, Nor Aini Jamil A. Wahab. FrieslandCampina: Ilse Khouw, Panam Parikh, Swee Ai Ng, Anne Schaafsma, Marjolijn Bragt. *Financial support:* SEANUTS was supported with a research grant from FrieslandCampina. FrieslandCampina was not involved in the recruitment of participants and the final set of results. *Conflict of interest:* None of the authors or the research institutes has any conflicts of interest. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of FrieslandCampina. *Authorship:* N.R., K.L.N.B., S., B.K.P., A.B., C.N.H., M.S. and J.E.W. contributed to the design of the study, data collection and data management. P.D. was involved in study monitoring, data management and data evaluation. Y.M. led the statistical analyses with the contribution and input from all authors. All authors contributed to the writing of the manuscript, critically reviewed and approved the final version of the manuscript for publication. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Medical Ethical Committees of the participating institutes. Written informed consent was obtained for all subjects by their parents and/or caregivers.

Supplementary material

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/S1368980015003316>

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