Growth Curves for School Children From Kuching, Sarawak: A Methodological Development

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Abstract
In this article, the authors propose reference curves for height and weight for school children in the Kuching area, Sarawak. The school children were from primary to secondary schools (aged 6.5 to 17 years old) and comprised both genders. Anthropometric measurements and demographic information for 3081 school-aged children were collected (1440 boys and 1641 girls). Fitted line plots and percentiles for height and weight (3rd, 10th, 25th, 50th, 75th, 90th, and 97th percentiles) were obtained. The height of school boys and school girls were almost similar at the start of their school-going age. For school girls, height and weight values stabilized when they reached 16 or 17 years old but kept increasing for school boys. School boys were taller than school girls as they entered adolescence. Height differences between school boys and school girls became significantly wider as they grew older. Chinese school children were taller and heavier than those of other ethnic groups.

Keywords
growth curves, height centile, weight centile, LMS method, school-aged children

Introduction
Growth is a complex biological process whereby a living organism increases in size until it reaches its point of complete development, both morphologically and functionally.¹,² A growth curve is the curve obtained by plotting increases in size or numbers against elapsed time. Growth reference has become one of the most acceptable guidelines to evaluate the well-being of an individual. Eveleth and Tanner³ stated that the average values of height and weight for school-aged children and adolescents indicate the status of a country’s public health, the norm of its citizens’ dietary condition, and indirectly, their quality of life as well.

Anthropometric measurements are used to access the growth status of children. A reference growth standard with which the growth status can be compared with is important for this assessment.⁴ The assessment of growth is important for health care providers and pediatricians to

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evaluate a child’s well-being in nutritional status and physiological needs and to identify any growth discrepancy. Unusual individuals with measurement for a particular trait that lies in one or the other tail of the reference distribution are also determined. Thus, reference data are central to growth monitoring because they help doctors diagnose growth-related conditions. Growth standards can be formed according to the ways in which samples are chosen: cross-sectional design, mixed longitudinal design, and longitudinal design. Most national growth standards, such as the US Center for Disease Control and Prevention (CDC 2000), British (UK 1990), Argentinian, Italian, and others are based on cross-sectional data.

In Malaysia, the World Health Organization (WHO) Growth Standards 2006 have been officially endorsed for growth monitoring. A large number of countries from Asia, the Middle East, and the Pacific have officially adopted the WHO’s new standards. Malaysian doctors have used both Centers for Disease Control and Prevention growth charts (CDC 2000) and the WHO chart to assess children’s growth. The need to develop a suitable single growth reference for screening, surveillance, and monitoring of school-aged children and adolescents has been prompted by increasing public health concern over childhood obesity as well as the lack of local reference for growth evaluation. Early studies on weight and height curves for Malaysian school children based on data sets obtained from measurements taken from Kuala Lumpur and Selangor state have been reported by Chen and Dugdale. However, a study to assess growth for height and weight involving a representative sample of children and adolescents in Kuching area, Sarawak, has yet to be undertaken.

**Materials and Methods**

**Sample Description**

Data collection took approximately 2 weeks in March 2009. Because of the high costs and time constraints, we considered only public schools in Kuching, the capital of the state of Sarawak, Malaysia. Our study protocol was reviewed and approved by the Board of Educational Planning and Research Division. Formal permission was then obtained from the Ministry of Education and Sarawak State Education Department before the study was conducted. A 2-stage stratified cluster sampling method was used (as simplified in Figure 1). In the first stage, 10 public schools were selected randomly from the total number of 133 schools, consisting of primary and secondary schools in rural and urban areas of Kuching. In the second stage, 2 classes in each grade were selected after consultation with the school principal. All students from the selected classes were invited to take part in this study. A total of 3081 school children (1439 boys and 1642 girls) aged 7 to 17 years old were included in the survey, which comprises about 2.3% of students from the Kuching area and 0.8% of the total population of school children in Sarawak. The sample selected is representative of Sarawak generally because the population of the Kuching area reflects the real distribution of major ethnic groups in the state. The school children sampled resided in both rural and urban areas. They were classified into 22 half-year age groups (which were divided into 6-monthly intervals for each age group).

The data and anthropometric measurements were collected and recorded with the collaboration of school teachers. The information for height and weight were taken from the students’ National Physical Agility Standard (SEGAK) handbook; recording of this information was made compulsory during physical education classes by the Ministry of Education in 2008. The SEGAK program covers both primary and secondary school children. Physical education teachers were given special training in taking the anthropometric measurements of school children, and the program is being continuously monitored by School Superintendents from the Ministry of Education. Only healthy school children were included under this program because unfit
students would not be able to carry out the entire agility test. Measurements were done during the physical education classes, which are either early in the morning for morning session classes or late in the evening for afternoon session classes.

Calibrated standard equipment was used for anthropometric measurements. For weight measurement, the portable HD 313 digital weighing scale (Tanita, Japan) and Seca 813 weighing machine (Seca, Germany) with self-zeroing function after each measurement were used. For height measurement, the portable Harpenden stadiometer (Holtain Ltd, UK) and Seca 217 stadiometer (Seca, Germany) were used. Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively.

Students were asked to complete a self-administered survey form providing demographic information such as gender, birth date, and other related socioeconomic characteristics. Ethnicity was included as one of the demographic characteristics because of the multiethnic nature of the Malaysian population. This provides an opportunity for examining the possible role of ethnic background in health issues. Teachers were asked to guide the students to complete the survey forms, especially the younger students in lower-primary schools. Students were assured that all forms would be coded for anonymity.

**Statistical Analysis**

The data were transferred from completed survey forms into Microsoft Excel spreadsheet 2007 for Windows. The data were first edited before being subjected to statistical analysis and curve
sketching. Data were sorted based on the inclusion and exclusion criteria. Incomplete survey forms, especially those without birth date, were excluded using the pruning technique. Pruning is necessary in data editing to remove superfluous information before analysis is carried out. For this purpose, scatter plots were used to find data outliers or unusual values and to identify the possible trends of the curve.

The data were analyzed using the Statistical Analysis Software \(^{17}\) (SAS Institute, Cary, North Carolina) and the MINITAB Version 14 \(^{18}\) (MINITAB Inc., State College, Pennsylvania) packages. Generalized means, which adjusted the data toward the median values for the height and weight of each age group, were obtained for plotting the curves.

Cole’s LMS method \(^{4}\) was used to construct smooth centile curves. The LMS method summarizes the changes in height and weight distributions by 3 curves representing skewness (L), median (M), and coefficient of variation (S) of the data at each age group. If \(A\) represents the measurement for a child of age \(t\) years, then the SD score (standard deviation score) or the \(z\) score is calculated as follows:

\[
z = \frac{A}{M(t)} - 1 \quad \text{for } L(t) \quad \text{and} \quad S(t).
\]

Height is usually normally distributed, but weight does not strictly follow a normal distribution. The WHO Multicenter Growth Reference Study Group \(^{12}\) suggested the application of a power transformation to age before fitting to enhance goodness-of-fit by the cubic splines technique for height and weight. The LMS method provides a way of obtaining normalized growth centile standards, which simplifies the SD scores form and deals with skewness that may be present in the distribution of measurements, such as height and weight. \(^{4}\) This method assumes that data can be normalized by using a power transformation, which stretches 1 tail of the distribution and shrinks the other tail simultaneously, thus removing the skewness.

Finally, after estimating \(L(t), M(t)\) and \(S(t)\) for each half-year age \((t)\), the 100\(\alpha\)th centile could be derived from

\[
C_{100\alpha}(t) = M(t)[1 + L(t)S(t)Z_{\alpha}]^{-\frac{1}{L(t)}}. \quad (2)
\]

For each set of percentile curves, this smoothing method was applied to 7 empirical percentiles (3rd, 10th, 25th, 50th, 75th, 90th, and 97th) for each gender and age group.

The LOWESS (locally weighted scatter plot smoothing) method was selected for curve smoothing. This procedure fits a regression surface to data through multivariate smoothing, fitting a function of the independent variables locally and in a moving fashion, analogous to how a moving average is computed for a time series. \(^{19}\) The MINITAB version 14 \(^{18}\) software was used to perform this method. Most applications use the degree of the local polynomial approximately to 2. However, the smoothing parameter varies until the curves approximate the data well. Curves will be oversmooth if the value chosen for the smoothing parameter is too high. For this study, the degree of smoothing of 0.6 was found to be suitable by trial and error.

**Results and Discussion**

A total of 10 public schools in Sarawak, comprising 5 primary and 5 secondary schools, took part in this study. The percentage of students from private schools in the Kuching area was negligible (3.2\%) as compared with those from the public schools (96.8\%). Furthermore, private school students come from more affluent family backgrounds; thus, a bias might occur as it does
not reflect the distribution of the major ethnic groups in Sarawak. The sampling error for this study was 0.5%, calculated based on the 95% confidence level and selection probabilities. The cross-sectional data on age, height, weight, and other demographic information were collected from 3081 school children, 46.71% of whom were male (n = 1439) and 53.29% female (n = 1642), ranging from 6.5 years old (primary 1) to 17 years old (secondary 5). About 3% of survey forms lacked birth date data and were removed from the analysis. For the purpose of accuracy, age was calculated in half years.

In Sarawak, the main population is made up of Chinese, Malays, and local indigenous tribes. These indigenous tribes comprise Ibans, Bidayuhs, Melanaus, and Orang Ulu. The number of Indian school children from Sarawak was not sufficient to be included in the analysis. Thus, in this study, the school children were categorized into 3 major ethnic groups: Malays, Chinese, and indigenous groups. Figure 2 shows the distribution of school children by ethnic group, including the Indian group, and Table 1 presents details about the basic sociodemographic background of the samples. Figures 3A and 3B show the growth curves for height and weight of school boys in Sarawak according to ethnic group, and Figures 4A and 4B show the growth curves for height and weight of school girls.

The means and SDs for height and weight of Sarawak school children are shown by ethnic group and gender in Table 2 and presented in the form of curves in Figures 3 and 4. These figures show that the various ethnic groups have similar heights and weights during the primary school period (6.5 to 12 years old). However, Chinese boys were taller and heavier from 12 years old onward (Figures 3A and 3B). Malay boys and those of other indigenous groups were similar in
**Table 1. Sociodemographic Background of the Sampled Individuals**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1439</td>
<td>46.71</td>
</tr>
<tr>
<td>Female</td>
<td>1642</td>
<td>53.29</td>
</tr>
<tr>
<td>Total</td>
<td>3081</td>
<td>100</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malay</td>
<td>756</td>
<td>24.54</td>
</tr>
<tr>
<td>Chinese</td>
<td>1618</td>
<td>52.51</td>
</tr>
<tr>
<td>Indian</td>
<td>8</td>
<td>0.26</td>
</tr>
<tr>
<td>Indigenous groups</td>
<td>699</td>
<td>22.69</td>
</tr>
<tr>
<td>Total</td>
<td>3081</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 3. A. Growth curves for height of Sarawak school boys by ethnic group. B. Growth curves for weight of Sarawak school boys by ethnic group

Figure 4. A. Growth curves for height of Sarawak school girls by ethnic group. B. Growth curves for weight of Sarawak school girls by ethnic group
height and weight. Among school girls, Chinese girls were taller and heavier than the other ethnic groups at most age groups (Figures 4A and 4B). The results of this study agree with the findings of Chen\textsuperscript{20} that Chinese school boys and girls from West Malaysia were taller and heavier than those of other ethnic groups.

Figures 5A and 5B show the smoothed height and weight curves for Sarawak school boys, and Figures 6A and 6B show the smoothed height and weight curves for the girls, using the 3rd,
Figure 5. A. Centile curves for height of Sarawak school boys. B. Centile curves for weight of Sarawak school boys

10th, 25th, 50th, 75th, 90th, and 97th percentiles. Figures 5 and 6 show the centile curves for the height and weight for school boys and girls, respectively. The data used in developing these centile curves incorporated all the ethnic groups in the Kuching area, Sarawak, so that it is suitable for use for all groups. Generalized mean height and weight were compared for each age group. Figures 5A and 6A show that the height of school boys and school girls, respectively, were similar at the start of school age (about 7 years old). However, by age 10, school girls were slightly taller than the boys (+0.5 to +2 cm). This implies that the girls had attained the growth spurt earlier than the boys. By 16 or 17 years old, the girls’ growth in height had begun to slow down, whereas that for the boys continued. El-Bayoumy21 had found similar results with Kuwaiti school children. Growth in weight for the boys and girls followed a similar pattern to that for height (Figures 5B and 6B). The gap between the 3rd and 97th percentiles was wide, suggesting a high variability for these measurements.
This study has shown that Chinese school children were taller and heavier than Malay school children and those of other ethnic groups at all ages. This may be true for school children from Sarawak because the Kuching area has the densest population (about 30% of the total population in Sarawak). In spite of this, the results could not be extrapolated or generalized to the whole Malaysian population. Previous studies by Chen²⁰ had also found the presence of ethnic differences in growth of height and weight, particularly in Kuala Lumpur and Selangor, Malaysia. The disparities in the growth rates of various ethnic groups are believed to be caused by environmental factors, such as socioeconomic background; cultural differences; and housing rather than genetic differences.⁶,²⁰ Nevertheless, the differences by ethnicity or race due to unequal distribution of privileges among subgroups appear to be diminishing.²²

The findings from this study indicate that the growth patterns among Sarawak school children have improved as a result of better nutrition and health care. However, the height and weight of Sarawak school children are still below those of school children from Western countries (as indicated by the CDC 2000 and WHO 2006 charts). Nevertheless, regional growth curves for school children from Thailand or Southeast Asian countries²³ were more comparable with the
Sarawak curves. In general, Sarawak school boys were slightly taller and heavier than Thai school boys at 17 years of age, but the height and weight for school girls were fairly similar for both countries.

The authors would like to point out that students from the public schools in the Kuching area attended either the morning or afternoon classes according to their age groups. As such, it was not possible to measure all the different age groups at the same time (either early in the morning or late in the afternoon), and the time difference could have led to a bias in weight measurement. However, this difference can be omitted because measurements for the same age group were conducted at the same time.

There were some limitations while conducting this study because cost and transportation posed some problems. The authors could not cover the whole state of Sarawak because it is the biggest state in Malaysia and has the largest rural area. Transportation caused a big problem, especially when travelling to remote, inaccessible areas of Sarawak.

**Conclusion**

The growth curve analysis presented in this article is part of a larger study to gain insight into the growth of infants and adolescents in Malaysia (Y B Bong, A A Shariff, A M Majid, and A F Merican, unpublished). The ongoing study covers all 5 major regions of the country, namely, the Northern, Southern, East, and West Coasts as well as East Malaysia (Sabah and Sarawak). These data sets will be combined to develop a growth chart for the Malaysian population. Thus, the results presented in this article cannot be generalized to the whole of Malaysia because the Kuching area is only one of the areas selected for the larger study. However, the development of reference growth curves suggested in this article will significantly contribute to the ongoing study conducted by the research team. Data obtained in this study will be combined with those from other states in Malaysia to produce a national reference standard. The setting up of growth reference curves for Malaysia is certainly required. The CDC and WHO growth charts, although they are currently being used locally, may not reveal the exact description of the individual and population growth because both charts were developed based on the US and European data sets.

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**Declaration of Conflicting Interests**

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