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Original Article

Reference Charts for Height and Weight of School Children from West Malaysia in Comparison with the United States Centers for Disease Control and Prevention

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Abstract

Background: Reference charts are widely used in healthcare as a screening tool. This study aimed to produce reference growth charts for school children from West Malaysia in comparison with the United States Centers for Disease Control and Prevention (CDC) chart.

Methods: A total of 14,360 school children ranging from 7 to 17 years old from six states in West Malaysia were collected. A two-stage stratified random sampling technique was used to recruit the subjects. Curves were adjusted using Cole's LMS method. The LOWESS method was used to smooth the data.

Results: The means and standard deviations for height and weight for both genders are presented. The results showed good agreement with growth patterns in other countries, *i.e.*, males tend to be taller and heavier than females for most age groups. Height and weight of females reached a plateau at 17 years of age; however, males were still growing at this age. The growth charts for West Malaysian school children were compared with the CDC 2000 growth charts for school children in the United States.

Conclusion: The height and weight for males and females at the start of school-going ages were almost similar. The comparison between the growth charts from this study and the CDC 2000 growth charts indicated that the growth patterns of West Malaysian school children have improved, although the height and weight of American school children were higher than those for West Malaysian school children.

Keywords: Centile curves, LMS method, LOWESS method, Growth charts, Malaysia.

Introduction

Human growth is influenced by both genetic and environmental factors (1). Environmental factors affecting human growth such as infectious disease and dietary intake are of particular importance in developing areas of the world (2). Growth rates vary according to gender and age; however, they tend to follow certain standard patterns. Regular assessment of growth in children is important for monitoring their health. Monitoring growth is an important task for health care providers to identify health or nutrition-related problems (3). In addition, screening for children to identify those who deviate from normal growth in a healthy population is an essential prerequisite prior to clinical investigation. Growth references are the most valuable and commonly-used parameters in evaluating the well-being of an individual. Anthropometric

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data such as body height and weight, and the associated indicators, such as height-for-age, weight-for-age and height-for-weight, can be used to detect and prevent growth-related diseases.

Reference centile curves are widely used in healthcare as a screening tool. These reference values are useful in providing insight as to whether physiological needs for growth and development are met. The centile curves identify subjects that display values of particular measurements which lie in one or the other spectrum of the reference distribution (4). For example, the individual at the 90th percentile for height is taller than 90% of his or her age-matched peers.

The pattern of growth in any age of a population changes with time; therefore, it is recommended that references should be updated regularly (5). For optimal monitoring purposes, recent reference growth data based on representative samples from the population are essential (1). International growth charts allow comparison between countries, but regional or national references are more useful in assessing local changes in nutritional status (6). Earlier studies on weight and height curves for Malaysian school children were published by Chen and Dugdale (7) in 1970. However, their data were collected from a small group of about 1,259 school children from the Kuala Lumpur and Petaling Jaya areas of the state of Selangor and not representative of the whole Malaysian population. Moreover, the study was conducted 40 years ago and secular changes must have occurred in children's growth pattern since then.

The purpose of development of the CDC 2000 growth charts (8), which was an improved version of the original NCHS 1977 growth charts, was to provide better estimation of size and growth by using more comprehensive national survey data and improved statistical smoothing procedures. These charts presently serve as a reference to evaluate physical size and growth for the majority of the pediatric population.

In the present study, the authors attempted to produce standard growth curves for school children from West Malaysia and to assess how well our children match with, or diverge from, the CDC 2000 growth charts. It is hoped that the growth curves would be useful for healthcare providers to monitor trends in growth, evaluate the impact of nutritional interventions indirectly in early childhood and to define the extent and severity of abnormal growth.

Materials and Methods

Data Sampling

For the purposes of data collection, West Malaysia was divided into two major regions, the East Coast and the West Coast. Six states were selected from the total of eleven states in West Malaysia. The East Coast states are Kelantan, Pahang and Terengganu while the West Coast states are Penang, Perak and Selangor.

Data were obtained from a cross-sectional sample of 14,360 school children (6,737 males and 7,623 females) from primary and secondary schools (Table 1). Data collection took approximately three months (March until May 2009) and it was carried out on the days when the students' attendance rate was high. Data collection was avoided on the days when the schools had events and examinations to maximize students' participation (9).

Since there were limited national survey data available, a proper mathematical equation could not be used to determine the sample size. As such, a two-stage stratified random sampling technique was used for the recruitment of subjects. Due to high costs and time constraints, only 1% of schools from the total number of schools in the West and East Coast regions of West Malaysia were selected in the first stage of sampling, consisting of both primary and secondary schools in rural and urban areas. In the second stage of sampling, two classes were chosen from each grade using simple random sampling without replacement. This was done after discussion with the respective school principals based on class schedules and the schools' administrative duties. This step is necessary to minimize interruption of the teaching and learning processes in the schools. Lastly, the cluster sampling technique was opted, with all (healthy) students from the selected classes participating.

The height and weight measurements for primary and secondary school students were reported in the survey forms made available to the schools. These measurements had been obtained by trained physical education teachers during physical fitness examination which was done twice yearly in accordance with the National Physical Fitness Standards for Malaysian School Students (NPFSMSS) program. This program was made compulsory by the Ministry of Education Malaysia since 2008. Only anthropometric measurements for healthy school children were included in this study since unhealthy students were not allowed to attend the physical education classes. An official circular as well as a handbook for this program were subsequently published (10). This programme is being continuously monitored by the School Superintendent from the School Inspectorate and Quality Assurance Division, Ministry of Education Malaysia to ensure that proper anthropometric and fitness examinations were carried out.

Standard equipment for anthropometric measurements was checked and calibrated at the beginning and end of each examining day for proper functioning and accuracy. For weight measurement, the portable HD 313 digital weight scale (Tanita, Japan) and Seca 813 weighing machine (Seca, Germany) with self-zeroing function after each measurement, were used. Students were asked to remove shoes, heavy outer clothing (such as jacket, belt) and items in their pocket before the measurement. Students were also asked to stand in the centre of the platform to ensure that the weight is distributed evenly to both feet. For height measurement, the portable Harpenden stadiometer (Holtain Ltd, UK) and Seca 217 stadiometer (Seca, Germany) were used. Students were asked to stand upright with their heads lifted (Frankfort horizontal plane) and heels placed together. Both weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. Measurements were made once with the teacher measuring the students and class representative recording the readings.

Each secondary school student was required to fill in the survey forms with their own height and weight. For lower primary school students, the survey forms were completed by their respective teachers with the available records. This was done to reduce errors and inconsistencies. Socio-demographic information including age, gender, race, geographic location (whether they live in rural or urban areas), number of siblings and family monthly income was also collected through the survey forms.

Age was recorded by calculating the difference between the date of data collection and the date of birth of the school children. The school children were divided into 22 age categories from 6.5 to 17.0 years old in increments of 0.5 years. The school children were also classified according to gender.

The data were first pruned to remove extreme values before statistical analysis and curve sketching were carried out. Incomplete survey forms and those which contained outliers were excluded from the analysis since these may affect the overall curve modeling. Scatter plots and box plots were used to locate the outliers or unusual values and to identify possible trends of the curves.

Statistical Analysis

The statistical packages used were SAS (Statistical Analysis System) Enterprise Guide (11) and MINITAB (12). When data are derived from cross-sectional surveys, raw nonparametric centiles of height or weight distributions conditional on age show irregular patterns (13). Height follows a normal distribution; however, weight distribution usually does not. Parametric test was conducted because the weight data can be transformed even though it is non-normal. In this study, reference curves were adjusted using Cole's LMS method (14). This method summarizes the changes in height and weight distributions by three curves representing the skewness (L), median (M) and coefficient of variation (S). A series of polynomial regression procedures were applied to smooth the L, M and S curves. For each function, the curve was sketched and goodness-of-fit test was carried out on each set of fitted data compared to the empirical ones. The best-fitting function was the one with the least error and non-significant p values. The LMS method using maximum penalized likelihood was used to perform model fitting of the anthropometric centile for the physical parameters (4). This method provided normalized growth centile standards which simplified the assessment (SD scores form), and dealt with skewness which may be present in the distribution of the measurements. The resulting LMS curves contained information for drawing centile curves and to convert measurements into exact SD scores using the formula (15)

$$SD \quad score = \left(\frac{\frac{measurement^{L(t)}-1}{M(t)}}{L(t)S(t)}\right) \qquad [1]$$

Where:

measurement is the height or weight values of the subjects.

The centiles were estimated from the following expression

$$C_\alpha = M[1 + LSZ_\alpha]^{\frac{1}{L}} \qquad [2]$$

Where:

L is the value of the parameter λ of the Box-Cox transformation;

M is the median of the original data;

S is the coefficient of variation of the original; data Z_α is the a centile of the normal distribution.

Generalized means (which adjusted the data towards the median values) were first computed in order to plot both height and weight curves for each age group. The LOWESS or "locally weighted scatter plot smoothing" method which uses locally weighted linear regression was then used to smooth the data.

Results

Figure 1 and 2 shows the smoothed centile curves for height and weight of male and female school children, respectively, according to their crude percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th). The number of female school children who participated in the study was more than that of male in West Malaysia.

Table 2 and 3 show the LMS and crude percentile values for height and weight of female and male school children.

Generalized mean heights and weights were compared for each different age group. As expected, males were taller and heavier than females for most of the age groups. The height and weight differed considerably especially as they entered adolescence (above 13 years old). At 11 and 12-year-old, females were taller (median value 141.80cm versus 139.52cm for 11-year-old and 148.19cm versus 146.29cm for 12-year-old) and heavier (median value 34.42kg versus 34.28kg for 11-year-old and 39.59kg versus 39.04kg for 12-year-old) than males in the 50th percentile. For females, height and weight values stabilized when they reached 15.5 and 16 years old, respectively. On the other hand, the height of males was still increasing after 17 years of age.

The height and weight centile plots for both genders obtained in this study and the Centre for Disease Control and Prevention (CDC 2000) (8) growth charts are shown in Fig. 3 and 4. The median centile curves of CDC 2000 showed that the male and female school children in The United States were taller and heavier than those in West Malaysia.

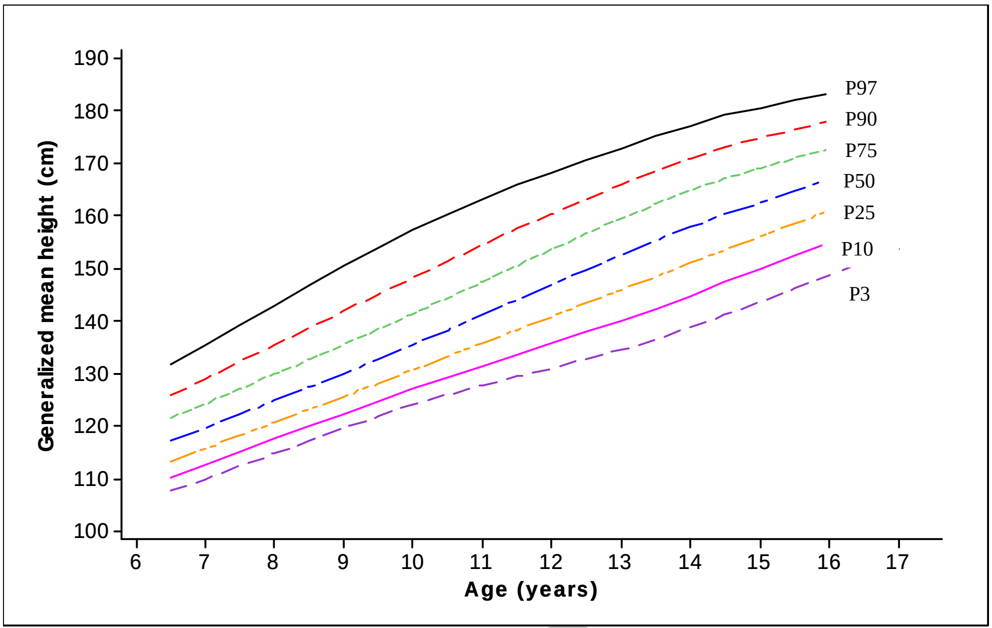

Fig. 1(a): The percentile plots for height of West Malaysian male school children

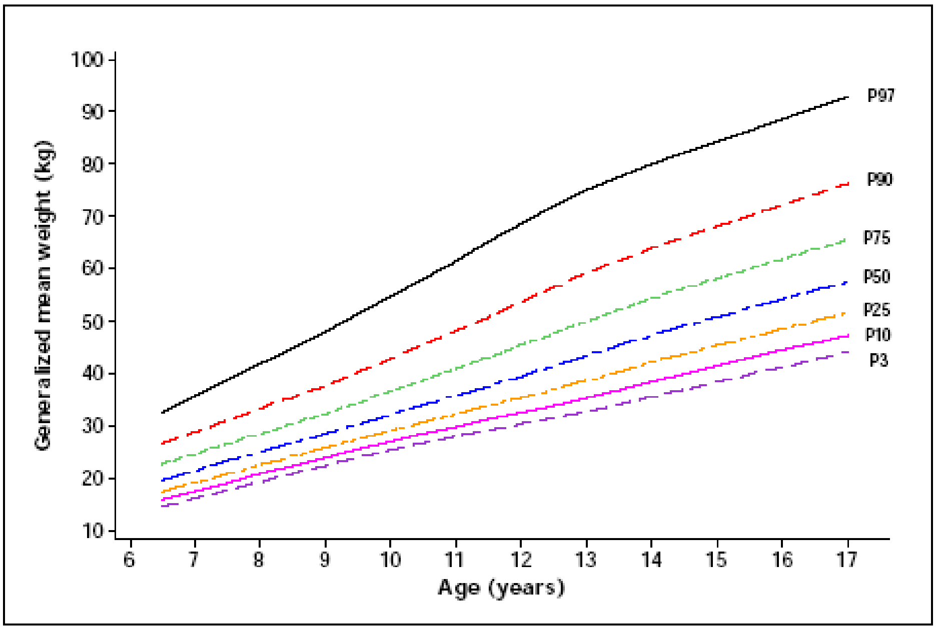

Fig. 1(b): The percentile plots for weight of West Malaysian male school children

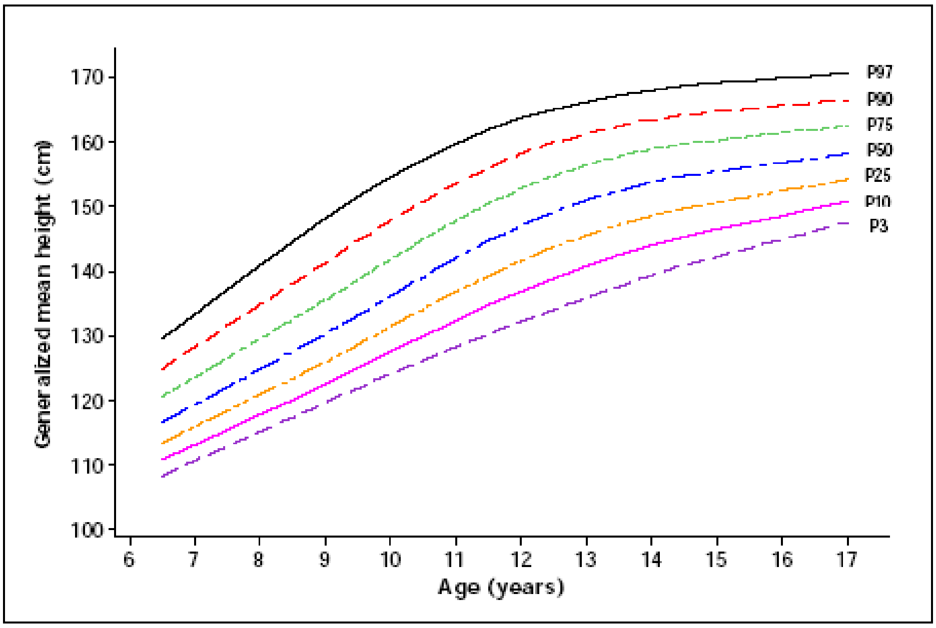

Fig. 2(a): The percentile plots for height of West Malaysian female school children

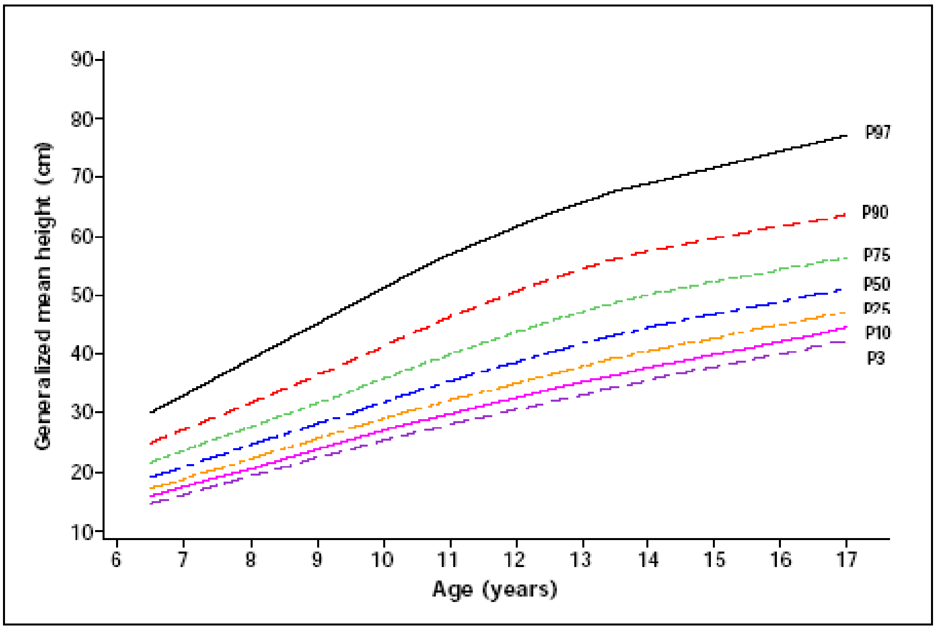

Fig. 2(b): The percentile plots for weight of West Malaysian female school children

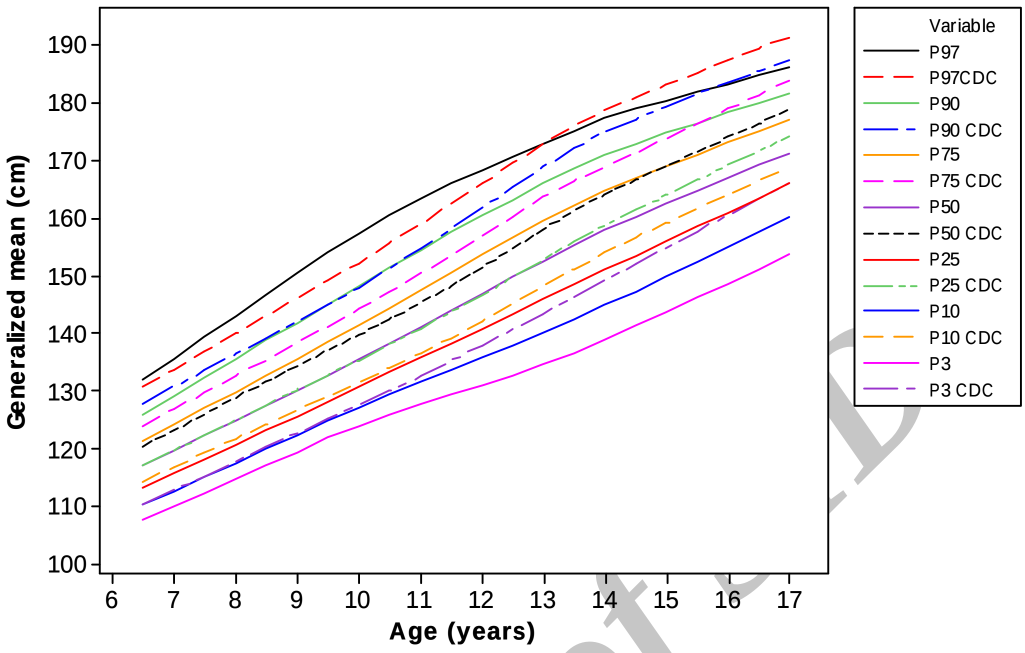

Fig. 3(a): Centile plots for height of West Malaysian male school children (____) and males in the CDC 2000 study (----)

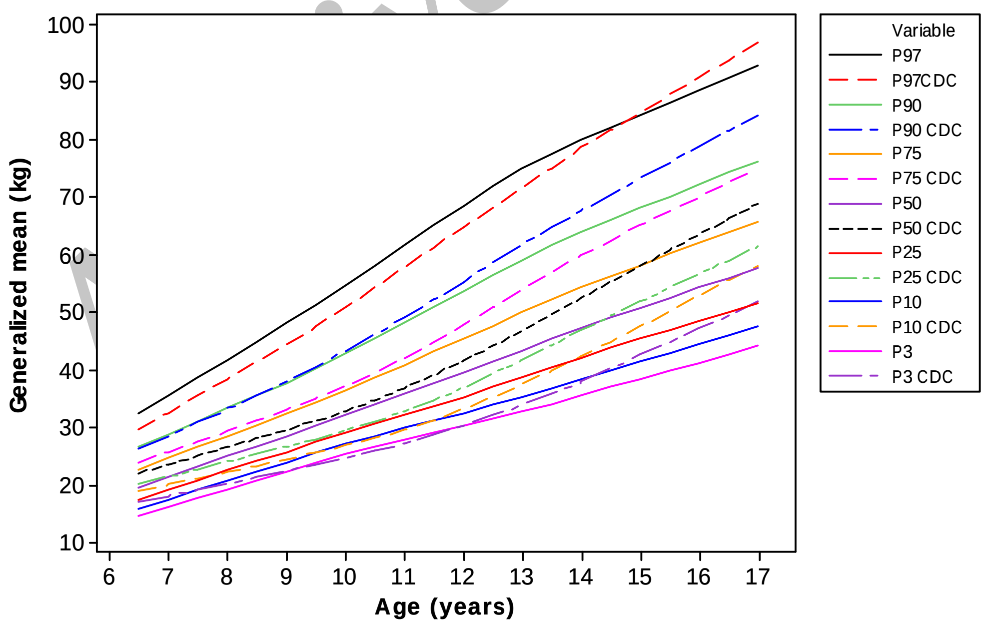

Fig. 3(b): Centile plots for weight of West Malaysian male school children (____) and males in the CDC 2000 study (----)

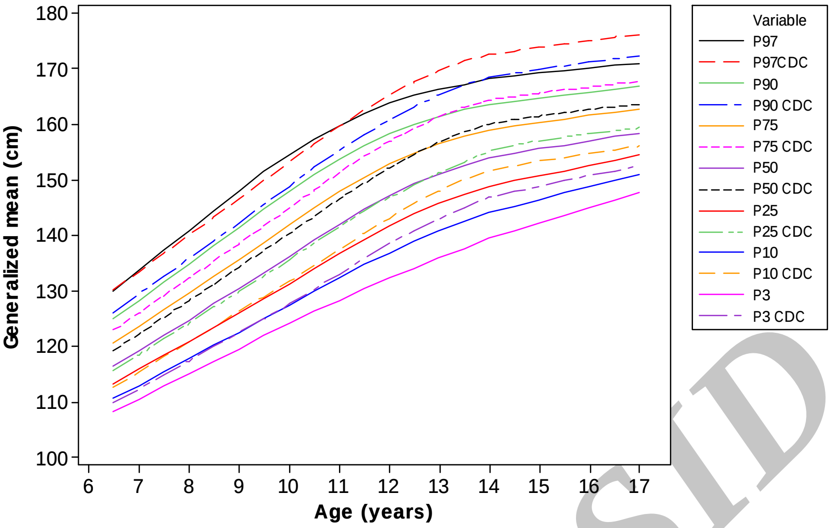

Fig. 4(a): Centile plots for height of West Malaysian female school children (___) and females in the CDC 2000 study (-----)

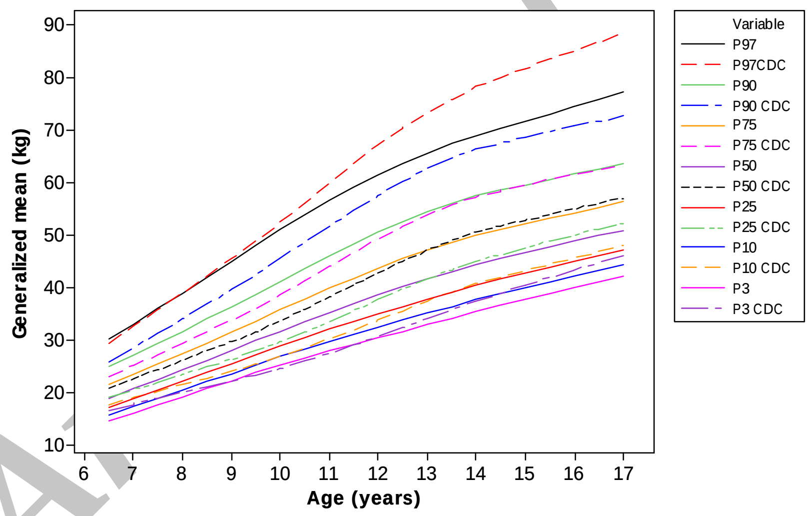

Fig. 4(b): Centile plots for weight of West Malaysian female school children (___) and females in the CDC 2000 study (-----)

Table 1: Number of schools and school children selected from each state by gender

States	Number of schools	Number of school children Male	Female	Total number of school children
Kelantan	10	1355	1448	2803
Terengganu	10	1284	1427	2711
Pahang	10	974	1052	2026
Perak	9	1310	1193	2503
Penang	10	757	1425	2182
Selangor	8	1057	1078	2135
Total	57	6737	7623	14360

Table 2: The LMS values and height percentiles for both male and female school children

Age	Gender	L	M	S	Percentiles						
					P3	P10	P25	P50	P75	P90	P97
6.5	M	-3.51	117.84	0.059	107.36	110.24	113.56	117.84	122.95	128.57	135.45
	F	-2.66	117.53	0.048	108.37	111.00	113.93	117.53	121.59	125.73	130.37
7.0	M	-1.57	119.56	0.047	110.03	112.85	115.91	119.56	123.52	127.40	131.54
	F	-3.43	118.77	0.045	110.26	112.68	115.39	118.77	122.64	126.66	131.26
7.5	M	-5.66	121.95	0.053	112.65	115.11	118.03	121.95	126.94	132.93	141.37
	F	-5.93	122.36	0.049	113.64	115.96	118.70	122.36	126.98	132.47	140.03
8.0	M	-5.33	122.69	0.051	113.60	116.04	118.91	122.70	127.40	132.86	140.13
	F	-6.21	121.75	0.048	113.38	115.61	118.24	121.75	126.20	131.48	138.81
8.5	M	-4.74	128.70	0.051	118.92	121.58	124.67	128.70	133.61	139.16	146.23
	F	-3.60	129.01	0.054	118.36	121.32	124.69	129.01	134.11	139.62	146.26
9.0	M	-4.75	129.17	0.053	119.02	121.76	124.96	129.17	134.34	140.25	147.93
	F	-3.54	129.06	0.054	118.38	121.35	124.74	129.06	134.16	139.67	146.26
9.5	M	-6.29	133.13	0.056	122.87	125.53	128.73	133.13	138.93	146.30	157.81
	F	-4.44	133.82	0.054	123.05	125.98	129.38	133.82	139.25	145.37	153.19
10.0	M	-5.34	134.40	0.062	122.70	125.75	129.40	134.40	140.96	149.19	161.65
	F	-4.66	134.81	0.059	123.35	126.41	130.02	134.81	140.82	147.85	157.32
10.5	M	-3.90	140.52	0.062	127.68	131.15	135.21	140.52	147.05	154.48	164.04
	F	-4.07	139.60	0.063	126.80	130.24	134.27	139.60	146.21	153.84	163.85
11.0	M	-4.69	139.52	0.055	128.19	131.24	134.81	139.52	145.36	152.08	160.91
	F	-2.23	141.80	0.059	128.39	132.21	136.49	141.80	147.85	154.08	161.14
11.5	M	-3.35	144.45	0.060	131.35	134.96	139.12	144.45	150.80	157.75	166.20
	F	0.55	146.42	0.058	130.80	135.69	140.73	146.42	152.21	157.51	162.82
12.0	M	-1.23	146.29	0.065	130.65	135.22	140.23	146.29	152.97	159.61	166.81
	F	1.54	148.19	0.055	132.33	137.49	142.62	148.19	153.66	158.50	163.19
12.5	M	0.21	150.66	0.067	132.57	138.13	142.97	150.66	157.59	164.06	170.63
	F	0.41	151.02	0.059	134.76	139.82	145.07	151.02	157.12	162.74	168.40
13.0	M	1.63	152.76	0.069	132.16	138.93	145.59	152.76	159.72	165.84	171.73
	F	2.78	152.15	0.054	135.04	140.89	146.42	152.15	157.51	162.09	166.38
13.5	M	-0.12	155.59	0.074	135.63	141.66	148.08	155.59	163.53	171.08	178.91
	F	1.21	153.32	0.052	138.12	143.00	147.91	153.32	158.68	163.49	168.20
14.0	M	1.96	158.37	0.067	136.98	144.12	151.04	158.37	165.39	171.49	177.30
	F	0.92	153.60	0.052	138.54	143.32	148.19	153.60	159.03	163.94	168.78
14.5	M	0.30	160.14	0.066	141.13	147.00	153.13	160.14	167.37	174.08	180.88
	F	0.38	154.92	0.045	142.03	146.06	150.22	154.92	159.71	164.11	168.51
15.0	M	1.21	163.10	0.060	144.62	150.55	156.52	163.09	169.60	175.42	181.12
	F	-0.20	155.46	0.046	142.70	146.63	150.74	155.46	160.37	164.95	169.61
15.5	M	2.43	166.13	0.055	147.47	153.77	159.80	166.13	172.13	177.30	182.18
	F	0.51	157.63	0.041	145.67	149.43	153.29	157.63	162.03	166.05	170.05
16.0	M	3.38	167.46	0.053	148.12	154.92	161.15	167.46	173.24	178.09	182.58
	F	1.16	157.91	0.042	145.36	149.38	153.43	157.91	162.37	166.37	170.30
16.5	M	0.26	168.75	0.051	153.16	158.00	163.04	168.75	174.61	180.03	185.49
	F	-0.86	157.37	0.041	146.04	149.48	153.13	157.37	161.84	166.07	170.45
17.0	M	1.78	168.35	0.052	151.17	156.80	162.36	168.35	174.19	179.32	184.27
	F	-1.35	157.08	0.041	146.01	149.34	152.89	157.08	161.54	165.83	170.33

Table 3: The LMS values and weight percentiles for both male and female school children

Age	Gender	L	M	S	Percentiles						
					P3	P10	P25	P50	P75	P90	P97
6.5	M	-1.23	20.29	0.194	15.01	16.33	17.97	20.29	23.39	27.30	32.93
	F	-1.67	19.62	0.164	15.30	16.39	17.73	19.62	22.16	25.40	30.24
7.0	M	-0.97	21.07	0.188	15.55	16.97	18.70	21.07	24.12	27.72	32.47
	F	-1.46	20.06	0.161	15.61	16.75	18.13	20.06	22.57	25.64	29.90
7.5	M	-2.14	22.65	0.183	17.50	18.73	20.30	22.65	26.14	31.37	42.25
	F	-1.70	22.76	0.191	17.20	18.55	20.26	22.76	26.31	31.20	39.55
8.0	M	-1.92	22.63	0.173	17.59	18.82	20.38	22.63	25.82	30.19	37.65
	F	-2.17	22.40	0.165	17.67	18.83	20.28	22.40	25.44	29.74	37.54
8.5	M	-2.22	28.31	0.172	22.20	23.67	25.54	28.31	32.36	38.29	49.99
	F	-2.25	27.82	0.160	22.11	23.50	25.26	27.82	31.48	36.63	45.78
9.0	M	-1.89	28.59	0.177	22.07	23.67	25.67	28.59	32.74	38.49	48.41
	F	-1.92	28.14	0.156	22.30	23.76	25.58	28.14	31.65	36.22	43.32
9.5	M	-3.20	30.93	0.132	25.76	27.01	28.60	30.93	34.35	39.49	50.83
	F	-3.50	30.51	0.125	25.72	26.88	28.35	30.51	33.70	38.55	49.83
10.0	M	-3.16	30.91	0.135	25.65	26.92	28.53	30.91	34.41	39.71	51.66
	F	-2.93	30.69	0.134	25.41	26.70	28.33	3069	34.09	38.97	48.51
10.5	M	-2.33	34.39	0.162	27.32	29.03	31.20	34.39	39.00	45.66	58.47
	F	-2.05	33.56	0.146	27.00	28.65	30.69	33.56	37.44	42.46	50.18
11.0	M	-2.25	34.28	0.159	27.27	28.98	31.14	34.28	38.76	45.05	56.42
	F	-2.45	34.42	0.156	27.59	29.25	31.35	34.42	38.85	45.26	57.61
11.5	M	-1.79	38.77	0.191	29.40	31.66	34.54	38.77	44.87	53.48	68.84
	F	-1.89	37.93	0.170	29.56	31.62	34.21	37.93	43.14	50.19	61.84
12.0	M	-1.75	39.04	0.192	29.50	31.80	34.73	39.04	45.21	53.87	69.14
	F	-1.46	39.59	0.194	29.57	32.04	35.14	39.59	45.76	53.88	66.55
12.5	M	-2.05	41.79	0.184	32.17	34.47	37.42	41.79	48.22	57.70	76.45
	F	-1.89	41.57	0.160	32.76	34.96	37.69	41.57	46.90	53.87	64.83
13.0	M	-1.65	42.75	0.188	32.38	34.92	38.11	42.75	49.26	58.07	72.55
	F	-2.40	41.61	0.181	32.46	34.61	37.40	41.61	48.05	58.33	83.99
13.5	M	-1.64	45.17	0.197	33.84	36.58	40.07	45.17	52.46	62.56	79.88
	F	-2.28	42.89	0.150	34.48	36.56	39.15	42.89	48.13	55.29	67.52
14.0	M	-1.64	46.19	0.190	34.87	37.64	41.12	46.19	53.32	63.01	79.05
	F	-2.21	43.38	0.151	34.78	36.91	39.57	43.38	48.70	55.90	67.96
14.5	M	-1.36	50.76	0.217	36.69	40.09	44.42	50.76	59.74	71.99	92.07
	F	-2.14	46.81	0.146	37.70	39.98	42.80	46.81	52.27	59.45	70.79
15.0	M	-1.40	51.43	0.186	38.70	41.88	45.83	51.43	59.00	68.66	82.97
	F	-2.22	47.14	0.144	38.12	40.38	43.17	47.14	52.59	59.78	71.31
15.5	M	-1.26	54.19	0.194	40.11	43.62	48.00	54.19	62.53	73.07	88.43
	F	-1.99	48.81	0.137	39.66	42.00	44.85	48.81	54.04	60.55	69.98
16.0	M	-1.55	54.23	0.176	41.38	44.58	48.56	54.23	61.95	71.93	87.07
	F	-2.33	49.28	0.153	39.53	41.92	44.93	49.28	55.46	64.08	79.45
16.5	M	-1.79	55.56	0.176	42.86	45.99	49.91	55.56	63.47	74.11	91.54
	F	-2.78	49.82	0.135	41.11	43.26	45.94	49.82	55.32	63.06	77.35
17.0	M	-1.72	56.39	0.177	43.34	46.56	50.59	56.39	64.43	75.15	92.33
	F	-3.35	49.34	0.120	41.71	43.58	45.93	49.34	54.22	61.25	75.16

Discussion

Female school children reach puberty earlier than male school children. However, the growth for females slows down after the age of adolescence. The percentile plots for height and weight of West Malaysia female school children reached the plateau at 15.5 and 16 years old respectively. In terms of weights, the gap between the 3rd and 97th percentiles of both genders for the West Malaysia school children charts were wider, suggesting greater variability for this trait. From the centile plots, it appears that the weight distribution tends to be skewed for both genders.

For the height parameter, the CDC 2000 median centile curves were superior to those obtained for males and females from West Malaysia. This is expected as it is known that Asians are generally shorter than Americans of the same age groups. However, for the 97th centile, male West Malaysian school children were taller at the start of school-age. This could be due to secular changes in growth that might have occurred in the last decade as suggested by So et al. (16). The data in the present study were collected in 2009 while the CDC reference charts used data from 2000. Female centile curves show that American girls were slightly taller than female school children from West Malaysia by a few centimeters for most of the percentiles (Fig. 4(a)). Despite this, the growth patterns of West Malaysian school children have improved due to the improvement in nutrition, healthcare and other factors. This must have been caused by rapid economic and industrial developments and better living standard of Malaysians in the last decade (17).

For the weight parameter, the 97th percentile for West Malaysian male school children show that they were significantly heavier than those presented in the CDC 2000 curves. In fact, local school children were heavier than children from the United States for several age groups, notably 8.5, 9.5 and 11.5 years old for males and 8.5 years old for females. When the median values for both sexes were compared, local school children reached their peak weights later than the children from the United States. The range between the weight centiles showed great variation, especially during adolescence. The present increase in consumption of fast food among school children must have significantly influenced their weight. Saturated and trans- fats inherent in fast food contain higher calorific values which increase energy intake and thus increase the risk of obesity (18). The general tendency for males to weigh heavier than females is similar to the growth patterns found in other countries (8, 19).

In this study, the height and weight for males and females at the start of school-going ages were almost similar. However, the differences between them became considerably bigger as they grew older. Males tend to be taller and heavier than females. The comparison between the growth charts from this study and the CDC 2000 growth charts indicated that the growth patterns of West Malaysian school children have improved, although their heights and weights, on average, were still lower than those of school children from the United States.

It is hoped that this study will provide an impetus for further research in an effort to obtain a national growth standard for Malaysia. The growth chart would be revised periodically as necessary in response to changes in environmental factors, nutritional state and living conditions.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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