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Height, Weight and Body Mass Index by Age and Sex in Children Aged 4 to 6 Years in Merida, Mexico, as Compared to International References After Normalization with LMS

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ABSTRACT

A cross-sectional study was done in 2006–2007 of 458 children (218 boys and 240 girls) aged 4 to 6 years (range 4.00 to 6.99 years) in Merida, Mexico. Height (cm) and body weight (kg) were measured to estimate growth; body mass index (BMI, kg/m^2) was calculated to evaluate nutritional status. Results showed significant sex difference with respect to height, weight, and BMI. Increment of height and weight with age was observed. However, age difference in BMI was not consistent. Nutritional status was evaluated using International Obesity Task Force (IOTF) classification and BMI cut-off values showed notable rates of overweight (boys 14.41% and girls 17.75%) and obesity (boys 12.43% and girls 7.21%). Anthropometric data of height, weight, and BMI were normalized using LMS methodology and were compared with World Health Organization (WHO) growth reference data. Again, increment of height and weight with age was observed although those were lower in the present study for boys and girls than the corresponding WHO growth reference data. In contrast, mean BMI by age in the present results exceeded WHO reference data, especially above the 85th percentile. Assessment of nutritional status with reference to IOTF and WHO revealed similar trends.

Key words: *children, growth, nutrition, height, weight, body mass index*

Introduction

Child growth and nutritional status are important public health indicators for communities and countries. A country's development can be gauged by monitoring child growth and nutrition and comparing the results with standard databases such as those of the World Health Organization (WHO)[1,2] and Centers for Disease Control and Prevention (CDC)[3,4]. Variations in environmental and genetic attributes, differences in eating habits and nutrition, physical activity, family socio-economic characteristics and overall quality of life influence child growth and development in different populations[5–9]. Public health professionals, human biologists and anthropologists have focused considerable effort on generating population databases for countries, including ethnic and genetic background.

To derive quantitative comparisons, it is convenient smoothing and normalizing cross-sectional growth and nutrition data from a specific population, before comparison with any standard reference. Mathematical methods such as LMS[10] are useful in normalizing empirical and asymmetrical data such as anthropometric measurements. Normalizing centile curves of variables allow growth trend interpretation along with child and adolescent nutritional status evaluation[11–17]. The LMS method summarizes a variable distribution using curves representing the skewness (L), median (M), and coefficient of variation (S) with a Box-Cox Power Exponential[16]. This same smoothing procedure has been used in British studies[13,15,18] and was applied to develop the reference centile curves of the WHO[1,2] and CDC[3]. Studies have been done building child growth and nutrition databases and com-

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paring them with standard growth charts in Australia,[19] Bahrain,[20] Kuwait,[21] Japan,[22] the United Arab Emirates[4] and Argentina[9]. No study of this caliber has yet been done representing any population in Mexico, although child growth and nutrition research has been done. One school-based study[23] conducted in two Mexico City neighborhoods, involved collection of height and growth data for children aged 3 to 20 years, normalizing the data by LMS and comparing them to two previous studies in the region. Reports[24,25] based on the National Health Survey 2000 (Encuesta Nacional de Salud – ENSA 2000) and other studies on growth in school-age children and adolescents above 6 years of age in the southern state of Oaxaca[26] are available but the results are not comparable with the present study. No research of this type had been done in Yucatan State, but there are reports[27] on child and adolescent growth and nutrition from Yucatan. However, those were done well over a decade ago and did not produce data comparable to those in the present study or any standard reference.

To address this lack of comparable data in the Yucatan region, a study was done of height and weight variation by age in a sample of children aged 4 to 6 years in Merida, Yucatan, Mexico, with four principal aims: 1) to evaluate child nutritional status using BMI-based cut-off values for thinness, overweight, and obesity recommended by the International Obesity Task Force (IOTF) [28,29]; 2) to verify z-score results of height-for-age (HAZ), weight-for-age (WAZ), and BMI-for-age (BMIZ) for the studied sample according to WHO standard references[1,2]; 3) to evaluate child growth status using weight-for-height z-scores; and 4) to normalize the collected anthropometric data of height, weight, and BMI using LMS method and compare the results with WHO growth reference data[1,2] by age and sex.

Materials and Methods

The study was carried out in Yucatan State, located approximately 1500 kilometers east of Mexico City on the Yucatan Peninsula, in southeast Mexico. Merida, the state's capital, is also its largest city. The study population consisted of 458 children (218 boys and 240 girls) aged 4 to 6 years (age range 4.00 to 6.99 years) in the city of Merida. This cross-sectional study was done between September 2006 and February 2007 in kindergarten schools located in the south of Merida[30]. Data were collected as part of a research project on the effects of migration on growth in children and the sample was not a representative of either Merida or Mexico. Indigenous Maya and Mestizo populations predominate in Yucatan. Participants' ethnicity was identified based on paternal and maternal surnames: 24% of the children were representing Maya families (both parents with Maya surnames), and 76% were from Mestizo families (at least one non-Maya surname). Socio-economic level in the group was generally poor with a low monthly family income (mean=US$200). Education level of the participants' parents was low when 47% had an elementary school level or less education, 39% had middle school level, 2% had studied in high school and rest were illiterate.

Growth and nutritional status were assessed by recording participants' height (cm) and body weight (kg) following standard international protocols[31–34]. Height was measured with a standard GPM anthropometer (Siber and Hegner, Zurich, Switzerland) and body weight with an electronic scale (Seca, Germany, model no. 872). Equipment was validated and standardized following international protocols and the weight scale was zero calibrated. Body mass index (BMI, kg/m^2) was calculated according to the standard formula[31,33].

Decimal age to the nearest month at the time of recording anthropometric measurement was calculated using birth certificates. Nutritional status based on BMI was estimated using International Obesity Task Force (IOTF) mid-year age cut-off values[28,29]. Calculation of z-scores for height, weight, and BMI-for-age (HAZ, WAZ, BMIZ, respectively), and weight-for-height (WHZ) was done with a WHO software program[1,2].

The anthropometric data distributions were little positively skewed and the LMS methodology[11–16] was applied to normalize height, weight, and BMI for age in boys and girls. The LMS Chartmaker Pro (Version 2.4; Tim Cole and Huiqi Pan, copyright 1997–2008, Medical Research Council, UK) software package was used to process data. Outliers in the LMS data plots were eliminated by visual scrutiny. Centiles in terms of three age and sex-specific cubic spline curves were estimated. To produce a model with the best possible fit, estimation was done with maximum penalized likelihood beginning from initial values (L=3, M=5, S=3 edf with original age) up to a certain equivalent degree of freedom (edf). The edf values L=2, M=3, and S=2 were selected with rescaled age to attain significant change in deviance (D) values. Maximum possible data smoothing was reached when the z-score and Q-Q Plot (Worm Plot) distributions ceased to exhibit unrealistic outliers. The estimated percentiles for the anthropometric data were exported to a Microsoft© Excel spreadsheet to generate graphs and those were compared with the corresponding standard WHO growth reference data by age and sex[1,2]. Comparisons were done using anthropometric values at mid-year age in the WHO standard references[1,2] for height, weight, and BMI.

Student's *t*-test was done to identify any differences in mean values of anthropometric data between boys and girls, and a one-way ANOVA was used to identify any age differences in mean values of height, weight, and BMI. All statistical analyses were done using the SPSS (Version 13.00) program with a $p<0.05$ significance level. Ethical approval was obtained from the Bioethical Committee of the Center for Research and Advanced Studies (Cinvestav-IPN), Mexico, before commencement of the study. Verbal consent of children and their mothers was obtained before measurements.

Results

Overall (boys+girls) mean age (Standard deviation or SD in parentheses) of the studied children was 5.58 (0.80) years (Table 1), with no significant differences between

TABLE 1
DESCRIPTIVE STATISTICS OF AGE AND ANTHROPOMETRIC CHARACTERISTICS IN BOYS AND GIRLS FROM MERIDA, YUCATAN, MEXICO.

Variables	Both sexes (n=458)	Boys (n=218)	Girls (n= 240)	t	p
AGE (Years)	5.58 (0.80)	5.63 (0.81)	5.55 (0.78)	1.073	0.284
BW (kg)	19.51 (4.07)	20.11 (4.71)	18.97 (3.32)	2.975	0.003
HT (cm)	107.62 (6.25)	108.32 (6.65)	106.99 (5.81)	2.265	0.024
BMI (kg/m^2)	16.71 (2.21)	16.96 (2.46)	16.48 (1.92)	2.277	0.023
HAZ	–1.06 (0.96)	–1.13 (0.99)	–1.00 (0.93)	–1.404	0.161
WAZ	–0.07 (1.39)	–0.074 (1.63)	–0.072 (1.12)	–0.013	0.990
WHZ	0.83 (1.42)	0.91 (1.61)	0.77 (1.23)	1.037	0.300
BMIZ	0.71 (0.92)	0.84 (0.99)	0.59 (0.84)	2.795	0.005

Standard deviations are given in parentheses. BW = Body weight, HT = Height, BMI = Body Mass Index, HAZ = height-for-age z-score, WAZ = weight-for-age z-score, WHZ= weight-for-height z-score, BMIZ = BMI-for-age z-score.

TABLE 2
MEAN HEIGHT, WEIGHT AND BMI BY AGE IN BOYS AND GIRLS FROM MERIDA, YUCATAN, MEXICO.

Variables	Boys Age (years)				Girls Age (years)			
	4 (n=58)	5 (n=77)	6 (n=83)	ANOVA (*p*)	4 (n=64)	5 (n=98)	6 (n=78)	ANOVA (*p*)
HT (cm)	101.99 (4.77)	107.99 (3.03)	113.04 (5.06)	82.25 (<0.001)	102.65 (4.44)	105.95 (4.53)	111.86 (4.68)	76.18 (<0.001)
BW (kg)	17.97 (3.88)	19.50 (4.11)	22.17 (4.97)	16.65 (<0.001)	17.50 (2.97)	18.38 (2.78)	20.90 (3.34)	25.20 (<0.001)
BMI (kg/m^2)	17.14 (2.52)	16.57 (2.23)	17.19 (2.60)	1.48 (N.S.)	16.54 (2.05)	16.32 (1.86)	16.63 (1.91)	0.57 (N.S.)

Standard deviations are given in parentheses. HT = Height, BW = Body weight, BMI = Body Mass Index

boys and girls. In this age group (4 to 6 years), boys were taller and heavier than girls and consequently had higher BMI. Significant differences in height, weight, and BMI were observed between sexes. Mean z-scores for height, weight, and BMI for age, and weight for height were within normal range. No significant sex differences were observed in the mean z-scores, except for BMI.

The ANOVA showed significant age differences in height and weight (Table 2). Mean height and weight in boys and girls exhibited a positive age-trend, rising gradually from 4 to 6 years. However, BMI did not vary significantly with age in both sex, and mean BMI increased only marginally, with a decline at 5 years of age.

Mid-year age cut-off values for BMI (kg/m^2) distribution based on the IOTF classification[28,29] were compared with the present results (Table 3). Thinness had low prevalence in either sex in three studied ages. In contrast, remarkable number of boys and girls were overweight (boys = 14.41%; girls = 17.75%) or obese (boys = 12.43%; girls = 7.21%), although the frequencies of undernutrition, overweight, and obesity declined from 4 to 6 years. Overweight frequency was higher in girls while boys had higher rate of obesity (Figure 1). Chi-square test (χ^2 with Yates' correction = 3.98 at one degree of freedom, $p = 0.04$, two-sided) showed a statistically significant association between sex and overweight and obesity. That was also confirmed by a Fisher's exact test (two-tailed p-value = 0.04), indicating a significant association between overweight and obesity with sex. As a result, rates of nutritional status in boys and girls, specifically overweight and obesity prevalence were estimated and presented separately by BMI cut-off values.

Nutritional status prevalence for boys and girls was evaluated using z-scores[1,2] (not normalized) for height-for-age (HAZ), weight-for-age (WAZ), weight-for-height (WHZ), and BMI-for-age (BMIZ) within a ±3 SD range (Table 4). Most of the children in either sex were within the normal range, with a consistently higher proportion of girls than boys. Low prevalence of wasting (WHZ) and thinness (BMIZ) were observed in either sex (less than –2 SD of z scores). Trends of prevalence of thinness, overweight and obesity among children were similar in terms of nutritional status, whether using IOTF BMI cut-off values[28,29] or BMI z-scores calculated using the WHO software program[1,2]. Frequencies of overweight (>+1SD) and obesity (>+2SD) were higher in boys than girls when measured by BMIZ. Stunting or low height-for-age (less than –2 SD of HAZ) was remarkably frequent in both boys and girls.

Values for L, M, and S in the present results by height, weight, and BMI for age in boys and girls were compared

TABLE 3
PREVALENCE (%) OF NUTRITIONAL STATUS IN BOYS (N=218) AND GIRLS (N=240) FROM MERIDA, YUCATAN, MEXICO, CALCULATED USING BMI (kg/m²)* CUT-OFF VALUES

Age (Years)	BMI-based nutritional status (%)													
	Thinness or chronic energy deficiency (CED) grades III, II, I								Normal		Overweight		Obesity	
	Boys				Girls				Boys	Girls	Boys	Girls	Boys	Girls
	III	II	I	Total	III	II	I	Total						
4	-----	------	3.45	3.45	-----	1.56	4.69	6.25	65.52	67.19	17.24	18.75	13.79	7.81
5	-----	1.29	3.90	5.19	1.02	-----	2.04	3.06	72.73	70.41	11.69	20.41	10.39	6.12
6	-----	------	1.18	1.18	-----	1.29	2.56	3.85	71.43	74.36	14.29	14.10	13.10	7.69

*According to International Obesity Task Force (IOTF) BMI cut-off values (Cole et al. 2000, 2007).[28, 29] Mid-year age values are considered for comparison.

TABLE 4
HEIGHT, WEIGHT AND BMI FOR AGE, AND WEIGHT FOR HEIGHT (BASED ON WHO, 2006, 2007) Z-SCORE FREQUENCIES (%) AMONG BOYS (N=218) AND GIRLS (N=240) AGED 4 TO 6 YEARS IN MERIDA, YUCATAN, MEXICO.

Z-SCORES	Sex	Z-score levels						
		–3	–2	–1	Median	+1	+2	+3
HAZ	Boys (%)	3.20	15.52	40.18	39.73	1.37	0.00	0.00
	Girls (%)	1.67	11.67	36.67	48.33	1.66	0.00	0.00
WAZ	Boys (%)	0.00	5.02	25.11	49.77	8.68	5.02	6.40
	Girls (%)	0.42	3.33	15.42	66.25	10.00	2.91	1.67
WHZ	Boys (%)	0.00	0.46	2.65	59.36	24.84	8.15	4.54
	Girls (%)	0.00	0.83	4.17	60.00	22.50	7.08	5.42
BMIZ	Boys (%)	0.00	0.00	0.46	64.84	22.83	7.31	4.56
	Girls (%)	0.00	0.42	1.67	70.83	20.83	5.42	0.83

HAZ = height-for-age z-score, WAZ = weight-for-age z-score, WHZ= weight-for-height z-score, BMIZ = BMI-for-age z-score.

with the standard WHO growth reference data[1,2] (Table 5). Normalization of height, weight, and BMI with age using the LMS methodology provided good model fit in all cases with small corrections. After data smoothing, L (skewness) values were obtained for age-wise height, weight, and BMI. In the WHO growth reference database, L values are constant (1) for height in this age range. In the present results, some L values were higher or lower than the WHO reference by age, especially for BMI. A repeated trial to refit the LMS model using lower edf values (L = 2, M = 3, S = 2) improved data smoothing. Median (M) values for height and weight for age in the present study were lower than the corresponding WHO reference data for boys and girls aged 4 to 6 years. However, M values for BMI in the present study in all ages and both sexes exceeded the WHO reference values. These same trends can be seen in the distribution and comparison of BMI data between the present study and the WHO

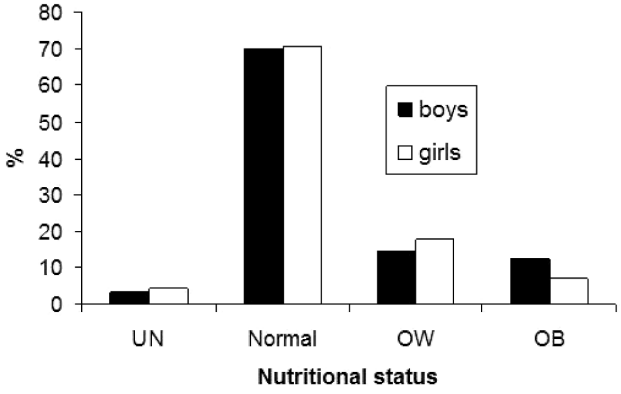

Fig. 1. Prevalence (%) of BMI-based nutritional status in children (218 boys and 240 girls) aged 4 to 6 years from Merida, Yucatan, Mexico (UN = Undernutrition; OW = Overweight; OB = Obesity)

TABLE 5
DISTRIBUTION OF L, M, AND S VALUES FOR HEIGHT, WEIGHT, AND BMI BY AGE IN BOYS (N=218) AND GIRLS (N=240) FROM MERIDA, YUCATAN, MEXICO.

Mid-year age (Years)	Variables (by age)		Boys			Girls		
			L	M	S	L	M	S
4	Height	PS	2.56	102.77	0.04	0.78	101.60	0.04
		WHO	1	106.67	0.04	1	106.17	0.04
	Weight	PS	–1.17	16.57	0.14	0.02	16.75	0.13
		WHO	–0.13	17.35	0.13	–0.34	17.16	0.14
	BMI	PS	–2.63	16.35	0.09	0.59	16.00	0.08
		WHO	–0.50	15.25	0.08	–0.57	15.25	0.10
5	Height	PS	–0.72	109.43	0.04	3.02	106.63	0.04
		WHO	1	112.91	0.04	1	112.18	0.04
	Weight	PS	–1.41	18.37	0.14	–0.60	18.15	0.13
		WHO	–0.25	19.39	0.13	–0.48	19.13	0.15
	BMI	PS	–2.79	16.20	0.10	–0.16	16.07	0.08
		WHO	–0.86	15.26	0.09	–0.98	15.25	0.10
6	Height	PS	–4.93	112.95	0.04	5.40	112.14	0.03
		WHO	1	118.87	0.04	1	117.98	0.04
	Weight	PS	–1.71	20.86	0.15	–1.54	20.54	0.12
		WHO	–0.38	21.68	0.14	–0.52	21.23	0.15
	BMI	PS	–3.08	16.65	0.12	–3.54	16.44	0.09
		WHO	–1.12	15.38	0.09	–1.17	15.32	0.10

PS= Present study; BMI= Body Mass Index.; WHO= World Health Organization

reference curves at 5th to 95th percentiles by age and sex. Coefficient of variation (S) values in the present study were similar to the WHO reference data for children of similar ages with a few exceptions. Overall, the results indicate increments in height, weight, and BMI with age and in the corresponding percentile levels. Once normalized, the present results exhibited noteworthy differences when compared with WHO standard growth reference curves for height, weight, and BMI for age in boys and girls. The smoothed curves for the present results have a similar appearance to the corresponding WHO reference centile curves, although this will require confirmation in future studies. Figures illustrating the above results are available from the corresponding author.

Discussion

The three analytical systems used in the present study for evaluating child growth and nutritional status (IOTF[28,29]; z-scores for height, weight, and BMI for age[1,2]; and data smoothing with the LMS method for comparison with WHO reference data[1,2]), exhibited similar trends in the results. The present results for growth and nutritional status of 4 to 6 year-old boys and girls in Merida, Yucatan, Mexico, showed increment of height, weight, and BMI by age. Mean height in boys was lower than girls at the age of 4 years but surpassed girls at 5 and 6 years. In contrast, body weight and BMI in boys were consistently higher than girls at all ages. Prevalence of overweight was higher in girls, but boys exceeded girls in frequency of obesity. Mean BMI was always higher among the boys than girls by age in relation to overweight or obesity. High overweight and obesity prevalence in children is a serious matter requiring immediate intervention by governmental and non-governmental agencies to promote healthy growth and nutrition in children. When normalized and compared with the WHO growth reference database, the children in the present study were found to have low height and weight for age. However, they had a BMI-for-age exceeding the WHO reference, a result of their low

height-for-age, which increased BMI in the present sample. Of particular note is the simultaneous occurrence of stunting or low height-for-age (less than –2SD of HAZ), and overweight and obesity (above +1 SD and +2 SD of BMIZ respectively) in the studied sample, which requires confirmation in future research using larger sample sizes and a wider age range. Previous studies[27] have mentioned the importance of body proportion and nutritional status of children and adolescents of different socio-economic levels in Yucatan and Maya populations. Studies[35] have also been done on body proportions in Maya children in Guatemala and the USA. This highlights the need for better understanding of the relationship between body proportion and nutritional status in these populations through the study of the allometric association of height and other body proportions with age and weight. The paucity of data in this area as well as the lack of a growth reference standard for Mexican children, and especially for Yucatan and Maya populations, preclude any extensive comparative discussion in the present study and emphasize the need to support the current findings with further research.

Similar studies in which anthropometric measurements for populations and/or countries are normalized for comparison with standard references are not widely available. In a study of height and weight for age centiles of children from 0 to 5 years of age in Jujuy province, Argentina,[9] the data were processed with the maximum penalized likelihood method and graphical comparisons were done with corresponding CDC and WHO centile references[2,3]. Centile values were lower than those two standard references, but the difference was not significant. In an Italian study,[36] the centiles and LMS curves for height, weight, and BMI in school children aged 6 to 20 years were compared with an Italian standard reference database. Using the LMS method to build growth charts of anthropometric measures, a study in the United Arab Emirates (UAE) of children aged 0 to 18 years compared the results with NCHS and WHO standards[4]. In a school health service study in Hong Kong, secular changes in height, weight, and BMI of children aged 6 to 18 years, recorded in two data series (1963 to 1993; 1993 to 2005–2006) were compared with IOTF cut-offs, showing a 5% increase in overweight and obesity[37]. Indeed, Chinese children have been reported as having higher BMI at all ages from 0 to 18 years when compared with US and British growth reference curves[38]. Finally, in a multicenter preschool-based study[39] in India, height, weight, and BMI of children aged 2 to 5 years were found to be below those standard references[1].

Applying the LMS methodology to anthropometric data is an effective way of monitoring growth and nutritional status from infancy through adolescence. Comparison of cubic splines (LMS values) provides good information for M values, while L values are more age-specific and depend on sample size. Comparison of S values between studies reveals little variation as long as the studies have used moderate to large samples because coefficient of variation by age is more meaningful in terms of biological changes during human growth. Among other reasons, the present study results are important because of the surprising combination of stunting, overweight, and obesity exposed in the normalized data, although a much larger sample size and extension to other age groups (<4 years and >6 years) is needed before broad trends can be discussed. In addition, a deeper understanding of child growth and nutritional status can be developed by expanding the range of data collected to include anthropometric measurements such as mid-upper-arm, waist and hip circumferences, as well as dietary habits and physical activity patterns. On a national scale, the LMS methodology needs to be applied much more broadly to generate comparable data for Mexico's hugely diverse population and ethnic groups, each with its own environmental, genetic, socio-economic, and dietary background. A concerted effort is also needed to analyze existing government anthropometric databases and compare them with international standard references. The present study constitutes an initial data contribution from a region almost completely lacking in child growth and nutritional status information, and will hopefully form the first step in an ongoing effort for further research and better understanding of this vital aspect of public health in Yucatan and Mexico as a whole.

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VISINA, TJELESNA MASA I INDEKS TJELESNE MASE PREMA DOBI I SPOLU KOD DJECE U DOBI OD 4 DO 6 GODINA U MERIDI, MEKSIKO, U USPOREDBI S MEĐUNARODNIM REFERENCAMA, NAKON NORMALIZACIJE S LMS ALGORITMOM

S A Ž E T A K

Presječna studija na 458 djece (218 dječaka i 240 djevojčica) u dobi od 4 do 6 godina (raspon 4,00 do 6,99 godina) provedena je 2006–2007. godine u Meridi, Meksiko. Visina (cm) i tjelesna masa (kg) su izmjerene kako bi se procjenio rast; indeks tjelesne mase (BMI, kg/m^2) je izračunat kako bi se procjenilo stanje uhranjenosti. Rezultati su pokazali značajnu razliku po spolu, u odnosu na visinu, tjelesnu masu i BMI. Primijećen je porast visine i tjelesne mase s dobi. Međutim, dobna razlika u BMI nije bila konzistentna. Stanje uhranjenosti je procjenjeno koristeći klasifikaciju Međunarodne radne skupine za debljinu (IOTF), a cut-off vrijednosti BMI pokazale su značajan postotak preuhranjenosti (dječaci 14,41% i djevojčice 17,75%) i debljine (dječaci 12,3% i djevojčice 7,21%). Antropometrijski podaci o visini, tjelesnoj masi i BMI su normalizirani koristeći LMS metodologiju i uspoređeni su s referentnim vrijednostima za rast Svjetske zdravstvene organizacije (SZO). Ponovno je primjećen porast visine i tjelesne mase s dobi, iako su one bile niže u ovoj studiji za dječake i djevojčice u usporedbi s odgovarajućim referentnim vrijednostima za rast SZO. Nasuprot tome, srednji BMI po dobi u ovim rezultatima je bio viši od referentnih vrijednosti SZO, posebice iznad 85. percentile. Procjena stanja uhranjenosti u odnosu na referentne vrijednosti IOFT i SZO je pokazala slične trendove.