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Physical growth of children and adolescents at moderate altitudes

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RESUMEN

Las evaluaciones del crecimiento físico son útiles para monitorizar el estado nutricional y para medir las desigualdades del desarrollo humano entre diferentes poblaciones. Los objetivos de esta investigación fueron: a) comparar el peso, la estatura e índice de masa corporal (IMC) con la referencia internacional CDC (Centros para el Control y la Prevención de Enfermedades); b) verificar si el IMC y/o el índice ponderal (IP) son aplicables a los niños y adolescentes que viven en altitudes moderadas; y c) proponer percentiles para clasificar el crecimiento físico. Este estudio incluyó a 3136 niños y adolescentes que viven en altitudes moderadas (2320 m). Se evaluaron el peso y la estatura. Se calcularon el IMC y el IP. En la muestra, las diferencias de peso se observaron en chicas de 10 a 17 años y en chicos de 12 a 17 años. Las diferencias de estatura se detectaron en los chicos de 10 a 17 años, mientras que en las chicas las diferencias se observaron a todas las edades. Para el IMC, las diferencias en los chicos comenzaron a los 15 años y en las chicas a los 14. En ambos sexos, la edad cronológica, el peso y la estatura influyeron en el IMC cuando se analizó por categoría nutricional (R^2=29-82%) y en general (R^2=16-66%). Estas variables influyeron levemente en el IP cuando se analizaron en general (R^2=0.01-0.06%) y por categorías nutricionales del IP (R^2=0.00-0.46%). En conclusión, los niños y adolescentes en altitudes moderadas difirieron en peso, estatura e IMC respecto a las referencias CDC. Se sugiere el uso del IP en lugar del IMC para clasificar el estado nutricional y de los percentiles propuestos en contextos clínicos y epidemiológicos.

ABSTRACT

Physical growth assessments are useful for monitoring the nutritional status and for gauging inequalities in human development among different populations. The objectives of this research were a) to compare variables of weight, height, and Body Mass Index (BMI) with the international reference for the Centers for Disease Control and Prevention (CDC); b) to verify if BMI and/or Ponderal Index (PI) are applicable to children and adolescents living at moderate altitudes; and c) to propose percentiles to classify physical growth. This study included 3136 children and adolescents living at moderate altitude (2320 m). Weight and height were assessed. BMI and PI were calculated. In this

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sample, weight differences occurred in females from 10 to 17 years old and in males from ages 12 to 17 years. For height, differences occurred in males from 10 to 17 years old while in females, differences occurred in all age groups. For BMI, differences in males began at age 15 and in females at 14 years. In both sexes, chronological age, weight, and height influenced the BMI when analyzed by nutritional category (R^2=29-82%) and in general (R^2=16-66%). These same variables mildly influenced the PI when analyzed generally (R^2=0.01-0.06%) and by nutritional categories of PI (R^2=0.00-0.46%). In conclusion, children and adolescents at moderate altitudes differed in weight, height, and BMI when compared to the CDC reference. The use of PI instead of BMI is suggested for classifying the nutritional status and the proposed percentiles in clinical and epidemiological contexts.

Introduction

The study of physical growth among populations is very important (Cameron & Bogin, 2012). For a long time, this has been the main objective in the fields of human biology and public health (Tanner, 1981; WHO, 1995). Given this context, biological research requires quantitative and qualitative documentation regarding size, shape, body composition, growth patterns, and development during childhood and adolescence (Cameron, 2013). The study of physical growth at high altitudes has a long history. This research studies the work of Baker, and his students in Nuñoa, Peru (Baker & Little, 1976), the first recognized by the anthropological community. However, only a few studies worldwide have been conducted at moderate altitudes, assessing the growth of children and adolescents using the WHO and CDC benchmarks (Cossio-Bolaños et al., 2012; Cossio-Bolaños et al., 2015a; Díaz Bonilla et al., 2018). These studies have shown that such references are not always suitable for assessing the growth of populations with specific geographical, cultural, and ethnic characteristics.

These findings emphasize the diversity and complexity in developing studies in extreme environments (Urlacher et al., 2016). This is especially true for moderate and high altitude cities since no physical growth references existed previously. Furthermore, the new WHO proposal and its original design only included children living at altitudes up to 1,500 meters above sea level (Ponce de León, 2008). Moreover, the United State CDC references (Kuczmarski et al., 2000; Fryar et al., 2012) do not report altitude as an adjustment factor. Therefore, growth and nutritional assessment status of children and adolescents belonging to the 6% of the world's population living at more than 1500 meters above sea level (Ponce de León, 2008) cannot use the above mentioned standards.

Thus, the few studies available about these groups suggest that growth patterns may differ due to several characteristics. These may include those related to growth rate, degree of sexual dimorphism, and low weight and height when compared to the references (Cossio-Bolaños et al., 2015a; Díaz Bonilla et al., 2018). Even the Body Mass Index (BMI), as an indicator of overweight, is considered unsuitable for school children at moderate altitudes (Cossio-Bolaños et al., 2012; Cossio-Bolaños et al., 2015b). In this sense, small populations at moderate altitudes – as in Arequipa (Peru), at approximately 2,320 meters above sea level need their own weight, stature, and body index curves. References are important and valuable tools for clinical practice, individual assessment, and physical growth monitoring. Additionally, they are used to classify and diagnose overweight and obesity in children and adolescents (Lobstein et al., 2004)

Therefore, the authors of this study hypothesized that children and adolescents living at moderate altitudes of Peru differ in weight, height, and BMI when compared to the CDC-2012 benchmarks (Fryar et al., 2012). Moreover, it is possible that the BMI is not applicable to this population, given that many drawbacks exist in its use in determining nutritional status of pediatric populations (Hosseini et al., 2017). This index does not completely correct height and may confuse growth differences among children (Doak et al., 2013). Thus, the Ponderal Index

(PI=Weight/Height3) may be a fundamental tool to adjust height differences of children and adolescents living at moderate altitudes in Peru. This information may be relevant for improving the comparison of nutritional status based solely on BMI.

Consequently, the objectives of this study included: a) to compare weight, height, and BMI with the CDC-2012 references from the United States; b) to verify if BMI and/or PI are applicable to children and adolescents living at moderate altitudes; and c) to propose percentiles to classify the physical growth of children and adolescents by age and sex.

Methodology

Sample and design

The study was descriptive (cross-sectional) and included 3136 students (1773 males and 1363 females) ranging in ages from 6.0 to 17.9 years old. They were selected non-probabilistically (non-random). All were students from four public elementary and secondary schools. Students attending these schools were, overall, an average socio-economic status. These schools are located in the urban area of Arequipa (2320 meters above sea level). The climate in the city is predominantly dry between April and November. During the year, the relative humidity ranges from 46% to 70%, and the temperatures vary from 10° to 25°C (Cossio-Bolaños et al., 2015a). Arequipa is considered to be an important center of industry, agriculture, and commerce in Peru. Peru's Human Development Index (HDI) in 2013 was 0.741, and Arequipa's was 0.745 (PUNDP, 2013). Figure 1 shows the location of Arequipa.

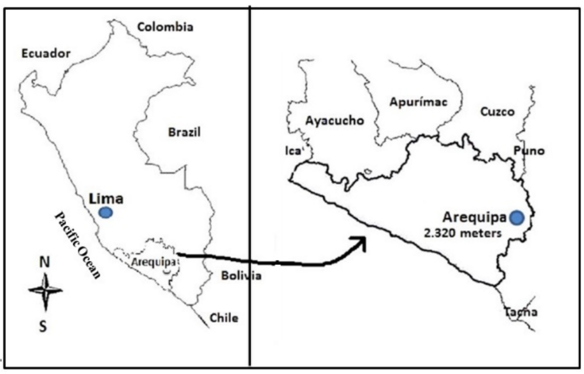

Figure 1. Map of Peru with the location of Arequipa.

For students to be included in the study, they needed to meet two criteria: to have a signed informed consent form parents or guardians and to have participated in the anthropometric assessment day. Exclusion criteria included the following: students not completing the anthropometric measurements, those not within the specified age groups, those with movement problems that hindered the anthropometric assessment, and students without informed signed consent. The research project was approved by all of the school boards. Also ethical approval was obtained from the Research and Ethics Committee (UCSM, Peru – 08/2016), prepared in accordance with the Declaration of Helsinki for Research with Human Subjects.

Procedures

The administrators of each school provided a worksheet with the students' birth dates. Data collection procedures were carried out in each school separately. The physical education departments trained to evaluate the anthropometric variables. Students were assessed from April to July 2017 during school hours (8:00 a.m. to 1:00 p.m.).

To evaluate weight and height, the protocol described by Ross and Marfell-Jones (1991) was used. Subjects were barefoot and wore shorts and t-shirts for weighing. A digital scale was used (Tanita Ltd., Japan) with 100g of precision and scale of 0 to 150kg. Subjects' height was also measured barefoot with the head positioned in the Frankfurt Plan. We used a Seca aluminum stadiometer graduated in millimeters, ranging from 0 - 2.50 m and with 0.1 cm precision was used to take the height measurements.

Body Mass Index (BMI) was calculated using the formula: BMI = Weight (kg)/ height2 (m), and the Ponderal Index (PI): PI = Weight (kg)/ height3 (m). Age categories were organized in intervals of 6.0 to 6.9 years, 7.0 to 7.9 years, and so forth until 17.0 to 17.9 years old. The cut-off points of the CDC-2012 were used to categorize the nutritional status, and to compare weight, height, and BMI (Fryar et al., 2012).

Quality control of the anthropometric measurements was determined by the Technical Error of Measurement (intra- and inter-evaluator). For this, 10% of the sample was evaluated, and, in both cases, the values ranged from 0.8 to 15%.

Statistical analysis

Kolmogorov-Smirnov test (K-S) was used to check the distribution normality for all anthropometric variables, based on age and sex. Quantitative variables were described as mean, standard deviation (SD), and amplitude. Categorical variables were described by absolute frequencies. Differences among sexes were tested through "t" test for independent samples. In turn, differences between reference, mean, and standard deviation values were determined by the "t" test for related samples. Chi-square was used to test the differences between nutritional categories (BMI and PI). Pearson's coefficient was used to evaluate the relationship between the predictive and dependent variables (BMI and PI). Subsequently, a linear regression analysis for age, weight, and height was performed, using these as independent variables and the BMI and PI as dependent variables (adjusted R^2 and Standard Error of the Estimate SEE). Percentile curves were built (p3, p5, p10, p25, p50, p75, p85, p90, p95, and p97) through the LMS method (Cole et al., 2000). The LMS was based on three smoothed curves: L(t) Box-Cox Power, M(t) median, and S(t) Variation coefficient. The software LMS Chart Maker version 2.3 (Pan & Cole, 2006) was used. Statistical calculations were performed in Excel and SPSS 16.0. The adopted significance level was $p<0.05$.

Results

Variables that characterized the sample studied are presented in Table 1. Males showed greater weight and height when compared to females ($p<0.05$). No significant differences occurred in BMI and PI among the subjects. When compared by BMI (p=3.053) and by PI (p=0.586), no significant differences occurred. In both indexes, the prevalence rates were similar.

Table 1. Anthropometric characteristics and body indexes of the sample studied, by sex.

Variables	Males		Females	
	$\overline{X}$	SD	$\overline{X}$	SD
Age (years)	12.4	3.6	12.2	3.6
Weight (kg)	47.0	16.1	43.2*	14.2
Height (cm)	164.5	17.3	143.5*	15.4
BMI (kg/m^2)	20.6	3.9	20.3	3.7
PI (kg/m^3)	14.0	2.4	14.2	2.4
BMI (prevalence)	**f**	**%**	**f**	**%**
Underweight	158.0	9.1	106.0	8.0
Normal	1234.0	71.2	987.0	73.9
Overweight	223.0	12.9	155.0	11.6
Obese	118.0	6.8	87.0	6.5
PI (prevalence)	**f**	**%**	**f**	**%**
Underweight	124.0	7.2	96.0	7.2
Normal	1246.0	71.9	986	73.9
Overweight	251.0	14.5	173.0	13.0
Obese	112.0	6.4	80.0	5.9

BMI = Body mass index, PI = Ponderal index, SD = Standard deviation, (BMI: X^2= 3.053, d.f. = 3, p = 0.383), (PI: X^2 = 1.934, d.f. = 3, p = 0.586), f = frequency, * p<0.05.

Comparisons of weight, height, and BMI in relation to the CDC-2012 are depicted in Figure 2. In all the variables, the average values increased as age advanced. For body weight, differences appeared earlier in females (at 10 years old) than in males (at 12 years old). With regard to height, differences occurred in males from 9 to 17 years old while in females, these differences appeared in all age groups. For males, differences in BMI appeared from ages 15 to 17 and for females, from 14 to 17 years old. Independent variables that influenced BMI and PI are presented in Table 2. In both sexes, the chronological age, weight, and height influenced BMI when analyzed by nutritional status categories (R^2 = 29-82%) and in general (R^2 = 16-66%). However, the same variables do not affect PI when analyzed in general (R^2 = 0.01-0.06%). However, when sorted by categories (R^2 = 0.00-0.46%), the effect values decreased dramatically with regard to BMI.

Tables 3 and 4 show the percentile distributions for weight, height, and PI by chronological age and sex. In both cases, the median values increased as age advances. The proposed percentiles are p3, p5, p10, p15, p25, p50, p75, p85, p90, p95, and p97.

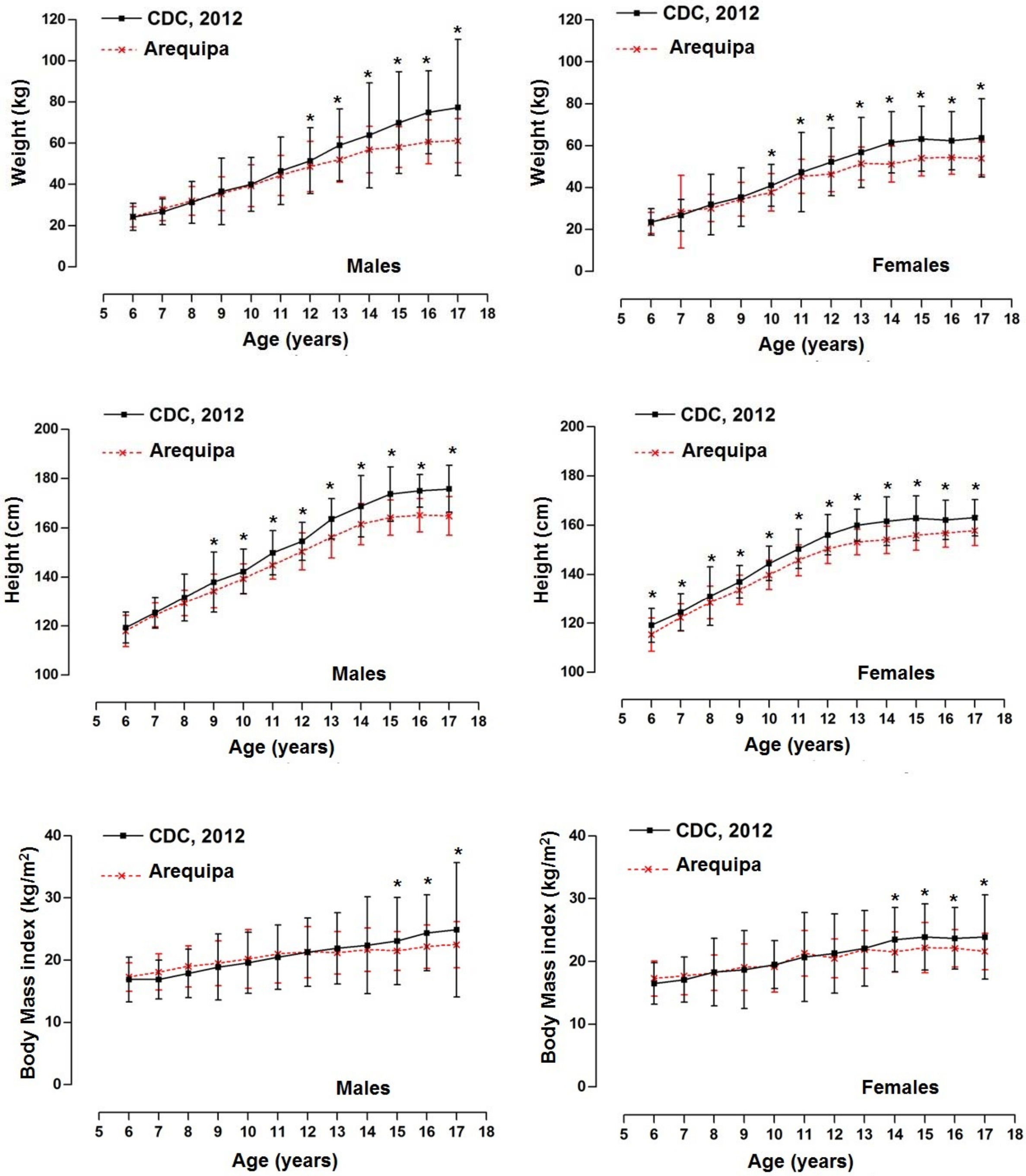

Figure 2. Comparison of mean values and standard deviation of weight, height, and BMI of students in Arequipa (Peru) with the CDC-2012 benchmarks.

Table 2. Variables affecting the BMI and PI of children and adolescents who live in moderate altitudes in Peru, by sex and weight class.

Indicators		Males				Females				Both			
		R	R^2	SEE	p	R	R^2	SEE	p	R	R^2	SEE	p
BMI (kg/m²)													
Underweight	Age (years)	0.89	0.79	0.68	0.001	0.78	0.61	1.04	0.001	0.84	0.71	0.86	0.001
	Weight (kg)	0.89	0.79	0.68	0.001	0.89	0.79	7.57	0.001	0.88	0.78	0.74	0.001
	Height (cm)	0.81	0.65	0.89	0.001	0.74	0.55	1.14	0.001	0.78	0.6	1.00	0.001
Normal	Age (years)	0.69	0.47	1.72	0.001	0.71	0.51	1.66	0.001	0.7	0.49	1.70	0.001
	Weight (kg)	0.84	0.7	1.29	0.001	0.88	0.77	1.13	0.001	0.85	0.72	1.25	0.001
	Height (cm)	0.66	0.43	1.78	0.001	0.71	0.51	1.67	0.001	0.68	0.46	1.75	0.001
Overweight	Age (years)	0.83	0.69	1.09	0.001	0.80	0.64	1.10	0.001	0.81	0.66	1.13	0.001
	Weight (kg)	0.88	0.77	0.95	0.001	0.91	0.82	0.77	0.001	0.89	0.89	0.88	0.001
	Height (cm)	0.81	0.65	1.17	0.001	0.83	0.69	1.02	0.001	0.82	0.67	1.11	0.001
Obese	Age (years)	0.62	0.38	2.75	0.001	0.57	0.32	2.19	0.001	0.59	0.34	2.59	0.001
	Weight (kg)	0.78	0.6	2.19	0.001	0.80	0.64	1.60	0.001	0.79	0.62	11.96	0.001
	Height (cm)	0.54	0.29	2.94	0.001	0.57	0.33	2.18	0.001	0.56	0.32	2.64	0.001
All	Age (years)	0.41	0.16	3.48	0.001	0.45	0.20	3.29	0.001	0.46	0.18	3.34	0.001
	Weight (kg)	0.81	0.66	2.25	0.001	0.72	0.52	2.55	0.001	0.81	0.66	2.14	0.001
	Height (cm)	0.43	0.18	3.44	0.001	0.45	0.20	3.30	0.001	0.45	0.20	3.30	0.001
PI (kg/m³)													
Underweight	Age (years)	0.59	0.34	0.55	0.001	0.33	0.11	0.68	0.001	0.48	0.24	0.61	0.001
	Weight (kg)	0.52	0.27	0.58	0.001	0.10	0.01	0.72	0.001	0.37	0.14	0.65	0.001
	Height (cm)	0.65	0.43	0.52	0.001	0.34	0.11	0.68	0.001	0.53	0.28	0.59	0.001
Normal	Age (years)	0.39	0.15	0.17	0.001	0.19	0.03	1.14	0.001	0.30	0.09	1.18	0.001
	Weight (kg)	0.14	0.02	1.26	0.001	0.06	0.00	1.16	0.001	0.08	0.01	1.23	0.001
	Height (cm)	0.40	0.16	1.16	0.001	0.23	0.05	1.13	0.001	0.35	0.12	1.16	0.001
Overweight	Age (years)	0.67	0.46	0.60	0.001	0.53	0.28	0.58	0.001	0.62	0.38	0.61	0.001
	Weight (kg)	0.44	0.20	0.73	0.001	0.30	0.09	0.66	0.001	0.41	0.17	0.70	0.001
	Height (cm)	0.56	0.31	0.68	0.001	0.42	0.18	0.63	0.001	0.52	0.27	0.66	0.001
Obese	Age (years)	0.16	0.03	1.94	0.001	0.28	0.08	1.48	0.001	0.20	0.04	1.75	0.001
	Weight (kg)	0.11	0.01	1.95	0.001	0.00	0.00	1.54	0.001	0.07	0.00	1.79	0.001
	Height (cm)	0.22	0.05	1.94	0.001	0.25	0.06	1.49	0.001	0.23	0.05	1.74	0.001
All	Age (years)	0.21	0.04	2.32	0.001	0.09	0.01	2.39	0.001	0.17	0.03	2.28	0.001
	Weight (kg)	0.25	0.06	2.30	0.001	0.25	0.06	2.33	0.001	0.26	0.07	2.23	0.001
	Height (cm)	0.24	0.06	2.30	0.001	0.16	0.03	2.37	0.001	0.22	0.05	2.26	0.001

BMI = Body Mass Index, PI = Ponderal Index, SEE = Standard Error of the Estimate, R= Correlation Coefficient, R^2= coefficient of determination.

Table 3. Percentile distribution of weight, height, and Ponderal Index for boys in moderate altitudes of Peru.

Age	n	L	M	S	P3	P5	P10	P15	P25	P50	P75	P85	P90	P95	P97
								Weight							
6.0-6.9	120	-0.59	23.39	0.20	16.7	17.4	18.5	19.3	20.6	23.4	26.9	29.1	30.8	33.6	35.6
7.0-7.9	147	-0.57	27.05	0.20	19.1	19.9	21.2	22.2	23.7	27.0	31.2	33.9	35.9	39.2	41.7
8.0-8.9	168	-0.54	30.63	0.21	21.5	22.4	23.9	25.0	26.7	30.6	35.5	38.6	40.9	44.8	47.6
9.0-9.9	105	-0.50	34.24	0.21	23.8	24.8	26.5	27.8	29.8	34.2	39.7	43.3	45.9	50.3	53.5
10.0-10.9	89	-0.47	38.09	0.21	26.3	27.5	29.4	30.8	33.1	38.1	44.3	48.2	51.1	56.1	59.6
11.0-11-9	94	-0.45	42.22	0.21	29.2	30.5	32.6	34.2	36.7	42.2	49.0	53.3	56.6	61.9	65.8
12.0-12.9	157	-0.47	46.41	0.21	32.3	33.7	36.0	37.7	40.5	46.4	53.7	58.3	61.8	67.5	71.7
13.0-13.9	165	-0.50	50.46	0.20	35.7	37.1	39.6	41.4	44.2	50.5	58.1	62.9	66.5	72.5	76.8
14.0-14.9	217	−0.55	54.01	0.19	38.9	40.4	42.9	44.7	47.7	54.0	61.7	66.6	70.3	76.3	80.6
15.0-15.9	174	−0.63	56.75	0.18	41.8	43.3	45.8	47.6	50.5	56.8	64.4	69.2	72.8	78.7	83.0
16.0-16.9	214	-0.72	58.76	0.17	44.2	45.6	48.1	49.8	52.7	58.8	66.2	70.8	74.3	80.1	84.2
17.0-17.9	123	-0.82	60.26	0.16	46.2	47.6	50.0	51.7	54.4	60.3	67.4	71.8	75.2	80.7	84.6
								Height							
6.0-6.9	120	3.02	118.43	0.04	107.5	109.0	111.2	112.7	114.7	118.4	121.9	123.7	124.9	126.6	127.7
7.0-7.9	147	1.77	123.85	0.04	113.1	114.5	116.6	118.0	120.1	123.9	127.6	129.5	130.8	132.7	134.0
8.0-8.9	168	0.76	129.07	0.05	118.3	119.6	121.7	123.1	125.2	129.1	133.0	135.1	136.6	138.7	140.1
9.0-9.9	105	0.18	134.22	0.05	123.1	124.4	126.6	128.0	130.1	134.2	138.4	140.7	142.3	144.6	146.1
10.0-10.9	89	0.14	139.52	0.05	127.8	129.2	131.4	133.0	135.2	139.5	143.9	146.4	148.0	150.5	152.2
11.0-11-9	94	0.49	145.10	0.05	132.5	134.1	136.5	138.1	140.5	145.1	149.8	152.3	154.0	156.6	158.3
12.0-12.9	157	1.08	150.81	0.05	137.2	138.9	141.5	143.3	145.9	150.8	155.7	158.3	160.0	162.6	164.3
13.0-13.9	165	1.78	156.28	0.05	141.6	143.5	146.4	148.3	151.1	156.3	161.3	163.9	165.7	168.3	169.9
14.0-14.9	217	2.48	160.76	0.05	145.3	147.4	150.5	152.5	155.5	160.8	165.8	168.4	170.2	172.7	174.3
15.0-15.9	174	3.11	163.69	0.05	147.8	150.0	153.2	155.3	158.4	163.7	168.7	171.2	172.9	175.3	176.9
16.0-16.9	214	3.67	165.34	0.05	149.2	151.5	154.9	157.0	160.1	165.3	170.2	172.7	174.3	176.6	178.1
17.0-17.9	123	4.17	166.40	0.04	150.2	152.6	156.0	158.1	161.2	166.4	171.1	173.5	175.1	177.3	178.7
								Ponderal Index							
6.0-6.9	120	-0.94	14.03	0.14	11.2	11.5	11.9	12.3	12.8	14.0	15.4	16.3	17.0	18.0	18.8
7.0-7.9	147	-0.87	13.88	0.15	10.8	11.2	11.7	12.0	12.6	13.9	15.4	16.3	17.0	18.2	19.0
8.0-8.9	168	-0.80	13.76	0.16	10.6	10.9	11.4	11.8	12.4	13.8	15.4	16.3	17.1	18.3	19.2
9.0-9.9	105	-0.74	13.62	0.16	10.3	10.7	11.2	11.6	12.3	13.6	15.3	16.3	17.1	18.4	19.3
10.0-10.9	89	-0.73	13.49	0.17	10.2	10.5	11.0	11.5	12.1	13.5	15.2	16.2	17.0	18.4	19.3
11.0-11-9	94	-0.75	13.35	0.17	10.0	10.4	10.9	11.3	12.0	13.3	15.0	16.1	16.9	18.2	19.2
12.0-12.9	157	-0.81	13.15	0.17	9.9	10.3	10.8	11.2	11.8	13.2	14.8	15.9	16.7	18.0	18.9
13.0-13.9	165	-0.89	12.89	0.16	9.8	10.1	10.6	11.0	11.6	12.9	14.5	15.5	16.3	17.6	18.5
14.0-14.9	217	-0.98	12.65	0.16	9.7	10.0	10.5	10.8	11.4	12.6	14.2	15.2	15.9	17.2	18.1
15.0-15.9	174	-1.10	12.54	0.16	9.7	10.0	10.5	10.8	11.3	12.5	14.0	15.0	15.7	17.0	17.9
16.0-16.9	214	-1.23	12.58	0.15	9.8	10.1	10.5	10.9	11.4	12.6	14.1	15.0	15.8	17.0	18.0
17.0-17.9	123	-1.36	12.66	0.15	10.0	10.2	10.7	11.0	11.5	12.7	14.1	15.1	15.9	17.2	18.1

L: Box-Cox Power, M: median, S: coefficient of variation.

Table 4. Percentile distribution of weight, height, and Ponderal Index for girls in moderate altitudes of Peru.

Age	n	L	M	S	P3	P5	P10	P15	P25	P50	P75	P85	P90	P95	P97
Weight															
6.0-6.9	107	−1.24	22.00	0.21	15.9	16.5	17.4	18.1	19.3	22.0	25.7	28.4	30.6	34.6	38.0
7.0-7.9	121	−1.04	25.68	0.21	18.5	19.2	20.3	21.1	22.5	25.7	29.9	32.8	35.1	39.2	42.4
8.0-8.9	121	−0.76	29.22	0.20	20.9	21.7	23.0	24.0	25.6	29.2	33.8	36.8	39.1	43.0	46.0
9.0-9.9	86	−0.45	33.18	0.20	23.4	24.4	26.0	27.2	29.1	33.2	38.1	41.2	43.6	47.4	50.1
10.0-10.9	106	−0.21	37.72	0.19	26.5	27.7	29.6	31.0	33.1	37.7	43.1	46.3	48.7	52.5	55.1
11.0-11-9	89	−0.07	42.43	0.19	30.0	31.3	33.4	35.0	37.4	42.4	48.2	51.6	54.0	57.9	60.6
12.0-12.9	121	0.02	46.34	0.18	33.0	34.5	36.8	38.5	41.1	46.3	52.3	55.8	58.3	62.2	64.9
13.0-13.9	133	0.08	49.35	0.17	35.6	37.1	39.6	41.3	43.9	49.4	55.4	58.9	61.4	65.2	67.8
14.0-14.9	122	0.09	51.32	0.16	37.6	39.1	41.5	43.3	45.9	51.3	57.3	60.7	63.2	67.0	69.5
15.0-15.9	125	0.05	52.67	0.16	39.2	40.7	43.1	44.8	47.4	52.7	58.5	61.9	64.3	68.0	70.5
16.0-16.9	113	0.04	53.40	0.15	40.3	41.8	44.1	45.7	48.3	53.4	59.0	62.3	64.6	68.2	70.6
17.0-17.9	119	0.08	53.71	0.14	41.0	42.4	44.7	46.3	48.8	53.7	59.1	62.2	64.3	67.7	70.0
Height															
6.0-6.9	107	0.96	115.42	0.05	103.8	105.2	107.5	109.0	111.2	115.4	119.6	121.9	123.4	125.7	127.1
7.0-7.9	121	0.95	121.91	0.05	110.2	111.7	114.0	115.5	117.7	121.9	126.1	128.4	129.9	132.2	133.6
8.0-8.9	121	1.08	128.22	0.05	116.5	118.0	120.3	121.8	124.0	128.2	132.4	134.6	136.1	138.4	139.8
9.0-9.9	86	1.39	134.31	0.05	122.6	124.1	126.4	127.9	130.1	134.3	138.4	140.6	142.1	144.2	145.6
10.0-10.9	106	1.84	140.17	0.04	128.4	129.9	132.2	133.8	136.0	140.2	144.2	146.3	147.8	149.8	151.2
11.0-11-9	89	2.25	145.48	0.04	133.7	135.2	137.6	139.1	141.4	145.5	149.4	151.5	152.9	154.9	156.2
12.0-12.9	121	2.48	149.75	0.04	138.0	139.6	141.9	143.5	145.7	149.7	153.6	155.7	157.0	159.0	160.2
13.0-13.9	133	2.48	152.71	0.04	141.2	142.7	145.0	146.5	148.7	152.7	156.5	158.5	159.9	161.8	163.1
14.0-14.9	122	2.21	154.60	0.04	143.3	144.8	147.0	148.5	150.7	154.6	158.4	160.4	161.7	163.7	165.0
15.0-15.9	125	1.65	155.92	0.04	144.9	146.3	148.5	149.9	152.0	155.9	159.7	161.8	163.1	165.2	166.5
16.0-16.9	113	0.82	156.90	0.04	146.2	147.5	149.6	151.0	153.0	156.9	160.8	162.9	164.3	166.4	167.7
17.0-17.9	119	−0.07	157.77	0.04	147.3	148.6	150.6	151.9	153.9	157.8	161.7	163.9	165.3	167.5	169.0
Ponderal Index															
6.0-6.9	107	−0.50	14.25	0.15	10.9	11.3	11.9	12.3	12.9	14.3	15.8	16.8	17.4	18.5	19.3
7.0-7.9	121	−0.58	13.87	0.15	10.6	10.9	11.5	11.9	12.5	13.9	15.4	16.4	17.1	18.3	19.1
8.0-8.9	121	−0.68	13.51	0.16	10.3	10.6	11.2	11.6	12.2	13.5	15.1	16.1	16.8	18.0	18.9
9.0-9.9	86	−0.78	13.25	0.16	10.1	10.4	10.9	11.3	11.9	13.3	14.9	15.9	16.7	17.9	18.9
10.0-10.9	106	−0.90	13.14	0.17	10.0	10.3	10.8	11.2	11.8	13.1	14.8	15.8	16.6	18.0	18.9
11.0-11-9	89	−1.04	13.17	0.16	10.1	10.4	10.9	11.3	11.9	13.2	14.8	15.9	16.7	18.1	19.1
12.0-12.9	121	−1.19	13.20	0.16	10.2	10.5	11.0	11.4	11.9	13.2	14.8	15.9	16.7	18.1	19.1
13.0-13.9	133	−1.35	13.26	0.15	10.4	10.7	11.1	11.5	12.0	13.3	14.8	15.9	16.7	18.1	19.2
14.0-14.9	122	−1.49	13.27	0.15	10.5	10.7	11.2	11.5	12.1	13.3	14.8	15.9	16.7	18.1	19.2
15.0-15.9	125	−1.58	13.23	0.15	10.5	10.8	11.2	11.5	12.1	13.2	14.8	15.8	16.6	18.0	19.2
16.0-16.9	113	−1.59	13.10	0.15	10.4	10.7	11.1	11.4	11.9	13.1	14.6	15.6	16.4	17.8	18.9
17.0-17.9	119	−1.54	12.88	0.15	10.2	10.5	10.9	11.2	11.7	12.9	14.3	15.3	16.1	17.4	18.5

L: Box-Cox Power, M: median, and S: coefficient of variation.

Discussion

The results of this research studying children and adolescents of both sexes from Arequipa showed similar patterns of growth and weight during childhood. However, during the teenage years, the average values become higher. Regarding height, boys, 6 and 7 years of age, from Arequipa presented linear patterns of growth similar to the CDC-2012 reference. Commencing at 8 years of age, their height was shorter than the reference. However, the average values of height for the females at all ages were significantly smaller when compared to the reference in all age groups.

Several studies performed in various parts of the world, independent of altitude, have shown differences in the physical growth of children and adolescents when compared with references from affluent countries (Hasan et al., 2001; Hakeem et al., 2004; Gómez-Campos et al., 2015; Urlacher et al., 2016). Even some studies conducted at moderate altitudes have confirmed relatively lower values of weight and height in comparison with the CDC reference (Cossio-Bolaños et al., 2012; Cossio-Bolaños et al., 2015a; Díaz Bonilla et al., 2018).

The differences found in this study and in previous research correspond to environmental and geographical influences. This suggests that the variation in body size, growth, and development patterns differ between populations (Walker et al., 2006). On the other hand, when comparing BMI values with the United States reference (CDC), no significant difference occurred in childhood. In turn, at advanced ages (15.0 to 17.0 in males and 14.0 to 17.9 in females), the differences began to appear. This phenomenon was recently observed in Colombian children. It showed that lower values of weight and height have a fundamental role on the BMI that leads to an excessive decrease of BMI in children and adolescents at moderate altitudes (Díaz Bonilla et al., 2018).

Other studies carried out in Peru already warned that BMI would not be applicable in student populations at moderate altitudes due to the shorter height based on the CDC and WHO references (Cossio-Bolaños et al., 2012; Cossio-Bolaños et al., 2015b), respectively. Therefore, based on these findings, this study sought to verify the applicability of BMI in a sample of students living at moderate altitudes in Peru. To do so, we used the reciprocal Ponderal Index (PI). From these, the explanation percentages for age, weight, and, especially, height were determined with regard to BMI and PI.

The results observed form this research are important for both sexes and in the four categories of nutritional status, age, weight, and height. They affect BMI at a higher percentage than the PI. When such variables are analyzed through PI, the effects decreased considerably and tended to disappear in a higher proportion of females than for males. This behavior may be a consequence of the slow linear growth observed in children and adolescents of both sexes, especially female adolescents.

Our findings are supported by other research. The results highlight that weight did not evolve according to height2 during growth and development (Burton, 2007; Peterson et al., 2017). Therefore, it is important to adjust the height to the cube to correct variations not only of stature but also of weight, especially for the biological maturation stage that influences body composition. Overall, it is important to emphasize that PI is a better tool for overweight classification than the BMI (Peterson et al., 2017). Moreover, PI is suitable for monitoring individual changes in the growth stage, and it can be used to compare people when no other quantitative or statistical information is available (Burton, 2007). Even though more studies are needed focusing on samples of populations living at moderate and high altitudes, more researchers are gradually beginning carry out more studies in this area to fill in the gaps. Thus, due to differences in physical growth patterns because of the smaller effects of age, weight, and height on the PI, this study produced percentiles values to sort the physical growth by age and type of school at moderate altitudes in Arequipa (Peru).

Regional percentiles need to be interpreted as references that allow description of the individual's growth and provide a common basis for comparing populations without making inferences about meaning (Turck et al., 2013). Even if these percentiles are uncommon in international literature, they are important for interpreting regional parameters for comparing populations living in similar geographical contexts. The cut-off points have been adopted in accordance with the international references (Cole et al., 2000; Kuczmarski et al., 2000; Fryar et al., 2012). However, in general, the definition of overweight in children is somewhat arbitrary (Moreno et al., 2005). As a result, the growth percentiles (standards and benchmarks) for children and adolescents became and issue to examine (Turck et al., 2013) and are currently under constant review. From the studies carried out by other research groups, differences arise in a number of aspects, such as age, ethnic origin, maximum growth rate, geographic environment (Gómez-Campos et al., 2014) among others. These may even cause an interpretation bias in the patient evaluation.

As far as we know, this is the first study that presents referential percentiles elaborated for PI using the LMS method. This information describes and characterizes weight, height, and PI of the children and adolescents at moderate altitudes of Peru. Moreover, it can complement the international references since government agencies and the United Nations base evaluations on growth charts to measure the physical well-being of populations as well as to formulate public policies, plan interventions, and/or supervise the effectiveness of the existing (de Onis, 2009). Some of the strengths of this study need to be highlighted since this research provides physical growth data from a larger sample (3196) and a wide age range (6.0 to 17.9 years old) unlike previous studies at moderate altitudes (Cossio-Bolaños et al., 2012; SON@-Rangel Group et al., 2015; Díaz Bonilla et al., 2018). In addition, this database can contribute significantly to contrast biological variation in terms of physical growth.

The study has also some weaknesses. For example, the cross-sectional design did not allow for drawing patterns of physical growth over time. Therefore, future studies need to consider a longitudinal design. Moreover, it was not possible to control the biological maturation. This would have for the comparison of the results based on chronological and biological age.

It is necessary to continue studying children and adolescents from different ethnic groups and geographic regions of the world. Therefore, differences in growth patterns and diagnostic limits of overweight and/or obesity can be compared between diverse populations.

Conclusion

Finally, the children and adolescents in this study living at Peruvian moderate altitudes differed in weight, height, and BMI when compared with CDC-2102 references. The effects of age, weight, and height, when analyzed through PI, presented much smaller values than when using BMI. We suggest the use of PI instead of BMI to classify nutritional status. In addition, the proposed percentiles can be used in clinical and epidemiological contexts.

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