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Regional variation in growth status. The Peruvian health and optimist growth study

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Abstract

Objective: This study aims to (1) investigate differences in weight, body mass index (BMI), and waist circumference (WC) among Peruvian children and adolescents living in three areas located at different altitudes; (2) compare age- and sex-specific height, weight, and BMI within each site with US reference data.

Methods: We sampled 8753 subjects (4130 boys), aged 4 to 17 years from sea level, rainforest, and high-altitude. Height, weight, and WC were measured and BMI was calculated. Analysis of variance was used to compare variables across geographic regions, and the Hoff and Blackburn procedure was used to compare the Peruvian results with US reference data.

Results: Participants living at sea level were taller, heavier, had greater BMI and WC relative to those living at high-altitude and in the rainforest. Peruvian schoolchildren of both sexes from the three geographical areas were shorter and lighter than their American peers. Boys and girls living in the rainforest and at high-altitude had lower BMI, whereas WC values of American schoolchildren are higher than those of the Peruvian children by age and gender.

Conclusions: Peruvians living at different altitudes differ in their growth indicators (height, weight, BMI, and WC), with significant differences between those living at sea level relative to their peers from other regions. Further, Peruvian schoolchildren of both sexes from the three geographical areas significantly differ from their US counterparts.

1 | INTRODUCTION

Human physical growth represents one of the best overall measures of population health and well-being, and has also been widely accepted as an indicator of nutritional status and quality of life in population-based research (Schell, 1986; Tanner, 1987). Recognized by its extraordinary plasticity and population heterogeneity (Ulijaszek, 2006), physical growth is affected by numerous factors, including genetic endowment and environmental exposures, whose simultaneous actions governing growth velocity and attained status at any age are complex and difficult to disentangle (Cousminer et al., 2014; Lettre, 2009; Thomis & Towne, 2006; Ulijaszek, 2006).

Growth is a powerful marker of population living conditions (Tanner, 1987), and researchers continue to study associations between different environments and various aspects of growth and development, mostly in low- and middle-income countries characterized by significant socioeconomic inequality (Krishna et al., 2015; Mansukoski et al., 2020). One such example is the country of Peru which spans three main geographic areas (sea level, Amazon region, and high-altitude), where children and adolescents are exposed to distinct environmental stressors and their daily life conditions are marked by economic, educational, nutritional, and health resource disparities (Gallup et al., 2003; INEI, 2018). In the past decade many areas of Peru experienced environmental, economic, and cultural changes, and notwithstanding a significant positive secular trend in physical growth, disparities in growth still remain among the three geographical areas (Hoke & Leatherman, 2019; Oths et al., 2018).

Altitude is a major environmental factor where socioeconomic and nutritional disparities tend to remain dominant factors interfering with child and adolescent growth, leading to pathological growth patterns, including low birth weight and intrauterine growth restrictions (Hartinger et al., 2006; Keyes et al., 2003), and growth retardation and shorter statures (Frisancho & Baker, 1970; Greksa, 2006; Weitz et al., 2000), which are usually linked with physiological adaptations to hypoxia (Mueller et al., 1980).

Approximately 30 million people reside between 2500 and 4400 m above sea level in the Andean cordillera (Stuber & Scherrer, 2010). It is assumed that native residents in such populations are adapted to their environments, characterized by an inheritance of physical traits selected during hundreds of generations to confer protection against the low content of oxygen (Baye & Hirvonen, 2020). It is well known that humans have an extraordinary capacity to adapt to diverse environmental constraints, like living at high-altitude, expressing their phenotypic plasticity (Lasker, 1969; Roberts et al., 1995). Hence, the growth processes of children living in the Peruvian Andes must be considered as a complex and multifactorial phenomenon, since numerous stressors included in what is designated a biology of poverty, generate a growth differential, without a single factor present having a complete explanatory power (Oths et al., 2018).

Previous research conducted in Andean communities in the Peruvian highlands revealed that the stunting of children living at high-altitude, when compared with children living at sea level, was a consequence of chronic hypoxia (Hartinger et al., 2006). However, other studies concluded that health and nutritional status deficiencies and poor access to health services were also partially responsible for the growth retardation of children and adolescents living at high-altitude (Leonard et al., 1990; Pawson & Huicho, 2010).

A recent report showed that Peruvian children were shorter, lighter and had higher body mass index (BMI) values than North-American and Argentinean counterparts; further, the waist circumference (WC) of Peruvian children was lower than North-American and Argentinean age- and sex-specific peers (Bustamante et al., 2015). More specific analyses revealed that Peruvian children and adolescents' physical growth timing and tempo were influenced by their living at different altitudes, with those living at sea level experiencing peak high velocity (PHV) at an earlier age, being taller at time of PHV, having a higher PHV, and having a taller estimated final adult height compared with those living at higher altitudes (Santos et al., 2019).

Data concerning growth trajectories among Peruvian children living at sea level are scarce and mostly compares them with their peers living at moderate altitude (Cossio-Bolaños et al., 2012; Crespo et al., 1995), while other data are from Japanese descendants living in the city of Lima (Shimabuku et al., 2009). Information concerning the growth status of children and adolescents living in the Amazon rainforest is almost nonexistent.

We contend that it is of importance to have a better understanding of children's distinct growth trajectories at local and regional levels when planning governmental policies and practices aimed to eradicate abnormal growth and poor health conditions. Hence, this study aims to: (1) explore differences in height, weight, BMI, and WC between three geographical areas located at different altitudes in Peru; and (2) compare Peruvians' average age- and sex-specific height, weight, and BMI within each site with the US Centers for Disease Control and Prevention (CDC) reference data (2007–2010) as proposed by Fryar et al. (2012). The following hypotheses were tested: (1) there are significant differences in height, weight, BMI, and WC across geographical areas, and (2) mean growth parameters in Peruvian children will be significantly lower compared with US reference data.

2 | METHODS

2.1 | Communities

Geographical heterogeneity in Peru is broadly expressed in three terrestrial areas: (1) the coast or coastal desert, located between the western mountains and the Pacific Ocean, which corresponds to 11.0% of the national territory with a subtropical desert climate; (2) the rainforest or Amazon region being the largest of the Peruvian territories which occupies 63.3% of its surface with a warm and rainy tropical climate; (3) the Andean region localized in the central part of the Andes mountain range comprising 26.0% of the national territory with a high mountain and mountain climate (SENAMHI, 2021). Of the 29 million Peruvian inhabitants, 54.6% live in coastal areas, 13.4% live in the rainforest, and 32.0% live in the mountain region; about 79.3% of the population resides in urban areas, while the remaining 20.7% live in rural areas. The population size of 0 to 19 year-olds is 40.5%, and between 20 and 60 years is 50.4% (INEI, 2018). The four cities of the present study were selected because they are located in different geographical areas of central Peru. Barranco is one of the 43 districts of the Lima Province, capital of Peru, and located on the shores of the Pacific Ocean. The average annual temperature is 18°C with a maximum in summer of 30°C, and in winter drops to 12°C. The districts of La Merced and San Ramon have geographical continuity and they are part of the Chanchamayo province located in the area of high forest (500–2000 m); its average annual temperature is 24.6°C, with a maximum of 30.4°C and a minimum of 20.4°C. The Junín district is the capital of the Junín province, located on a plateau at 4107 m on the southern shore of Lake Junin or Chinchaycocha; its temperature is frigid and varies between 7 and 12°C during the year. Comparative data for socioeconomic and educational indicators as well as health care conditions of these regions are displayed in Table 1.

2.2 | Design and participants

The present cross-sectional sample comes from the research project entitled "*The Peruvian Healthy and Optimistic Growth Study*," which investigates growth, development and health of children, adolescents and their families (Bustamante et al., 2011). A stratified random sample of 8753 children and adolescents (4130 boys and 4623 girls), aged 4 to 17 years, was collected from 31 public schools belonging to the four cities located in the three natural regions of central Peru (Table 2). All data were collected between March 2009 and December 2010. The chronological age of each child was based on the date of assessment and birth date obtained from school records.

After initial political and educational contacts with local authorities in each city, formal permission was

TABLE 1 Geographic, demographic, socioeconomic, educational, and health care characteristics of the three geographical areas located in the central region of Peru

Characteristics	Sea level (Barranco)	Amazon region (Chanchamayo)	High-altitude (Junín)
Geographic			
Altitude (m)	58	751	4107
Climate	Arid; semi-warm	Rainy; warm	Rainy; cold
Average annual temperature	18°C	24°C	12°C
Demographic			
Total population	8.564.867	411.011	1.272.890
Population density (people/km^2)	236.6	10.2	27.7
Socioeconomic			
Human development Index	0.72	0.52	0.44
Per capita family income (monthly)	1440.6	785.1	512.7
Primary production	Trade/tourism	Agriculture/tourism	Stockbreeding/agriculture
Educational			
School age children	15.829	13.960	2.703
Public	8.88 (56.1%)	11.13 (79.7%)	2.60 (96.2%)
Private	6.95 (43.9%)	2.83 (20.3)	10.2 (3.8%)
Urban	15.83 (100%)	12.93 (92.6%)	2.68 (99.1%)
Rural	0.0 (0%)	1.03 (7.4%)	25.0 (0.9%)
Boys	7.12 (45.0%)	7.17 (51.4%)	1.36 (50.3%)
Girls	8.71 (55.0%)	6.79 (48.6%)	1.34 (49.7%)
Basic access to health care			
Health center	Yes	No	No
Public hospital	No	Yes	Yes
Private clinic	Yes	No	No

TABLE 2 Number of school children assessed in the three geographical areas of the central region of Peru, according by age group and sex

Age (years)[a]	Sea level Barranco		Rainforest area Chanchamayo		High-altitude Junín		All areas	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
4	91	90	123	92	24	23	238	205
5	84	69	128	139	45	36	257	244
6	104	91	149	146	45	52	298	289
7	76	52	140	192	55	47	271	291
8	82	64	178	174	47	60	307	298
9	119	76	187	184	65	76	371	336
10	85	84	218	189	70	71	373	344
11	111	114	193	189	73	55	377	358
12	92	119	237	144	134	90	463	353
13	69	64	212	144	76	92	357	300
14	125	102	187	120	109	102	421	324
15	110	142	150	151	98	85	358	378
16	139	82	132	118	105	84	376	284
17	60	40	41	44	55	42	156	126
Total	1347	1189	2275	2026	1001	915	4623	4130

[a]Age classification in each group was as follows: for 10+ ages are between 10.00 and 10.99 and the same applies for all ages between 4 and 17 years.

asked from schools' governmental bodies to participate in the study. Written informed consent was obtained from parents. Further, all children signed an informed assent to freely participate in the study and that they may stop their participation whenever they wanted, without any obligation. The ethical committee and the Research Institute of the Enrique Guzmán y Valle National University of Education (UNE EGyV) approved the project (Res. No. 2459-2008-R-UNE).

2.3 | Anthropometric techniques

All measurements were made according to standardized techniques (Lohman et al., 1988). Stretched stature with head positioned in the Frankfurt plane was measured to the nearest 0.1 cm with a portable stadiometer (Personal Caprice Sanny®, Model ES-2060, São Bernardo do Campo, SP, Brazil) weight was measured to the nearest 0.1 kg using a digital scale (Pesacon, Model IP68, Lima, Peru), and WC was measured with a non-stretchable fiberglass tape (Sanny, model 4010, São Bernardo do Campo, SP, Brazil) at the midpoint between the edge of the lowest rib and the superior iliac crest during shallow apnea. The BMI was obtained by the following formula: BMI = weight (kg)/height $(m)^2$.

2.4 | Data quality control

Data quality control was conducted in two phases. In phase one, all team members were trained by experienced anthropometrists for accurate anatomical landmarking, subject positioning, and measurement techniques. In phase two, a random sample of 211 children and adolescents was re-measured during the first 3 weeks of data collection. Technical errors of measurement (TEM) were used to estimate the degree of precision in all measurements. Relative TEM values were 0.2 cm (0.09%) for height, 0.1 kg (0.53%) for weight, and 0.9 cm (1.38%) for WC.

2.5 | Statistical analysis

Data analysis was performed in a stepwise fashion to investigate the effects of geographical area on physical growth. Firstly, data cleaning, exploratory analysis, outlier identification, and normality checks were done. Secondly, using geographical area as a fixed factor, mean differences in height, weight, BMI, and WC within each sex were tested using analysis of variance. To control for multiple testing, a post hoc Bonferroni's adjustment was made. Thirdly, we relied on a technique developed by

Hoff and Blackburn (1981) to compare Peruvian growth data (height, weight, BMI, and WC) to US Centers for Disease Control and Prevention (2007–2010 CDC) (Fryar et al., 2012) means and *SD*, and percentiles for sex and age. Briefly, the method uses descriptive statistics (age- and sex-specific means, *SD*, and sample size) to firstly standardize individual stature, weight, BMI, and WC values into z-scores. From these z-scores, an F-ratio is calculated which is conservative in significance testing between the groups Hoff and Blackburn (1981). This approach was previously used in reports by Leonard et al. (1994) and Kim et al. (1991). All analyses were done in IBM-SPSS 25. The significance level was set at 5%.

3 | RESULTS

Weight, height, BMI, and WC mean and *SD* by age and sex according to the three different geographical areas are summarized in Tables 3 and 4. No significant differences ($p > .05$) were found in height and weight between the rainforest area and high-altitude children and adolescents. However, sea level schoolchildren are significantly ($p < .05$) heavier than those from the rainforest and high-altitude areas, except for 17-year-old girls. A similar pattern in height was observed (except for 15-year-old girls and 17-year-old boys). Regional differences in BMI occurred between 6 and 14 years in girls and 6 and 17 years in boys, favoring sea level schoolchildren. Boys' WC means differed significantly ($p < .05$) at all ages, while in girls these differences are evident between the ages of 4 and 14 years, with the exceptions being at age 13 and between the 15 and 17 years of age.

Figure 1 shows the 50th percentiles of weight, height, BMI, and WC of Peruvian schoolchildren residing in three geographical areas contrasted with US data (Fryar et al., 2012). In general, Peruvian schoolchildren of both sexes and of the three geographical areas are shorter and lighter than their American peers. For BMI, Peruvians living at sea level show higher values than their American counterparts, but only from 4 to 14 years; while children from both sexes living in the rainforest and at high-altitude have lower values across age. Finally, children of both sexes and of the three geographical areas have lower WC values than Americans; in boys this trend is more evident after 12 years of age.

Table 5 shows that, in general, Peruvian schoolchildren of both sexes and of the three geographical areas are shorter than their American peers, with males and females living at high-altitude presenting the lowest height values ($z = -1.34$ for males; $z = -1.27$ for females, $p < .001$, respectively). For weight, Peruvian girls and boys from sea level ($z = -0.15$ for males; $z = -0.27$, for females, $p < .001$), rainforest ($z = -0.59$ for males; $z = -0.62$, for females, $p < .001$), and high-altitude ($z = -0.74$ for males; $z = -0.82$ for females, $p < .001$) are lighter relative to Americans. For BMI, schoolchildren of both sexes living in the rainforest and high-altitude show lower values than their American peers ($z = -0.24$ and $z = -0.47$, $p < .001$ for males in the rainforest and at high-altitude, respectively; $z = -0.27$ and $z = -0.46$, $p < .001$ for females in the rainforest and at high-altitude, respectively). Finally, for WC, Peruvians of both sexes from the three geographical areas show lower values for WC than Americans ($z = -0.41$; $z = -0.55$, and $z = -0.77$, $p < .001$ for males at sea level, in the rainforest, and at high-altitude, respectively; $z = -0.47$, $z = -0.60$ and $z = -0.83$, $p < .001$ for females at sea level, in the rainforest and at high-altitude, respectively).

4 | DISCUSSION

The first aim of this study was to provide data on weight, height, BMI, and WC of Peruvian children and adolescents, aged 4 to 17 years, living in different geographical areas located at different altitudes. We found that girls aged 4–14 years, and boys aged 4–16 years, living in the rainforest and at high-altitude were shorter and lighter in comparison with their sea level peers. A similar growth retardation pattern was found in previous studies in youth living at high-altitude (Frisancho & Baker, 1970; Greksa et al., 1984; Weitz et al., 2000). The chronic hypoxia seems to slow down fetal growth and reduce uterine artery blood flow, causing a retardation of intrauterine growth. After birth, children living at high-altitude do not show catch-up growth, while postnatal growth rates seem to not differ in children residing in lowlands and high-altitude (Greksa, 2006). Poor health and nutritional status may play an additional role in explaining growth retardation in children living in these environmental conditions (Bailey et al., 2007; Pawson et al., 2001). When comparing our sample living at high-altitude (Junín) with those reported by Pawson et al. (2001) living in Marquiri and Tintaya, two high-altitude Peruvian communities from the Cuzco region, our sample was heavier (~2.6 kg in boys and ~ 1.3 kg in girls) and taller (~3.9 cm in boys and ~ 3.5 cm in girls) than their Marquiri peers, but shorter (~2.4.cm in boys and ~ 2.8 cm in girls) and lighter (~1.6 kg in boys and ~ 1.5 kg girls) than the Tintaya residents. Indeed, the Junín area provides a better socioeconomic condition for their children than the Marquiri community. On the contrary, the schoolchildren living in Tintaya were from families mostly working in the private mine company which was responsible for providing them

TABLE 3 Results of mean differences analysis between the three geographical areas for height and weight of schoolchildren from both sexes, aged 4 to 17 years

	Girls									Boys								
Age (years)	Sea level Mean	*SD*	Rainforest area Mean	*SD*	High-altitude Mean	*SD*	Level altitude difference F	*p*	Dif	Sea level Mean	*SD*	Rainforest area Mean	*SD*	High-altitude Mean	*SD*	Level altitude difference F	*p*	Dif
Height (cm)																		
4	105.6	5.79	102.6	4.11	100.6	3.40	15.37	.001	1 ≠ 2; 1 ≠ 3	106.8	4.50	102.9	4.31	103.4	4.16	19.16	.001	1 ≠ 2; 1 ≠ 3
5	112.6	4.61	108.3	4.58	106.1	5.09	33.74	.001	1 ≠ 2; 1 ≠ 3	112.4	4.63	108.7	4.67	107.6	4.45	18.52	.001	1 ≠ 2; 1 ≠ 3
6	115.5	5.55	111.9	5.46	111.2	3.95	17.26	.001	1 ≠ 2; 1 ≠ 3	116.1	4.67	112.2	5.50	112.9	4.21	17.70	.001	1 ≠ 2; 1 ≠ 3
7	121.3	6.10	117.6	5.06	117.0	4.80	14.68	.001	1 ≠ 2; 1 ≠ 3	123.7	6.06	118.1	5.06	117.8	5.36	24.23	.001	1 ≠ 2; 1 ≠ 3
8	127.4	6.34	122.8	5.55	124.7	4.93	19.18	.001	1 = 2; 1 ≠ 3	127.7	5.80	121.9	6.15	123.6	5.32	22.38	.001	1 = 2; 1 ≠ 3
9	133.3	7.39	128.3	5.85	127.5	5.44	27.73	.001	1 ≠ 2; 1 ≠ 3	132.1	5.63	127.7	5.57	128.4	4.92	18.13	.001	1 ≠ 2; 1 ≠ 3
10	139.8	7.61	133.8	6.98	133.9	6.19	24.52	.001	1 ≠ 2; 1 ≠ 3	136.5	6.71	132.0	5.83	131.7	5.25	18.80	.001	1 ≠ 2; 1 ≠ 3
11	145.3	6.91	141.1	7.09	139.6	6.27	19.33	.001	1 ≠ 2; 1 ≠ 3	141.7	6.32	137.1	6.49	136.5	6.85	21.00	.001	1 ≠ 2; 1 ≠ 3
12	148.4	4.98	145.5	6.97	144.8	5.48	10.32	.001	1 ≠ 2; 1 ≠ 3	151.2	8.82	141.7	7.56	142.5	5.72	58.27	.001	1 ≠ 2; 1 ≠ 3
13	152.0	5.58	149.5	5.33	147.7	5.05	11.53	.001	1 ≠ 2; 1 ≠ 3	157.1	7.96	148.8	8.68	147.2	7.73	30.50	.001	1 ≠ 2; 1 ≠ 3
14	153.0	5.25	150.1	5.35	150.3	5.13	13.13	.001	1 ≠ 2; 1 ≠ 3	161.5	7.74	154.7	7.21	154.7	8.16	26.95	.001	1 ≠ 2; 1 ≠ 3
15	153.6	5.37	151.7	5.27	151.8	5.20	4.81	.041	ns	163.2	6.46	158.8	6.12	160.5	6.55	18.12	.001	1 = 2; 1 ≠ 3
16	154.1	5.25	152.4	5.32	152.3	4.40	5.09	.022	ns	166.6	6.09	161.3	5.32	162.4	5.82	22.30	.001	1 ≠ 2; 1 ≠ 3
17	154.0	5.40	152.2	4.37	152.4	5.01	2.06	.258	ns	166.0	7.25	161.9	5.37	161.9	6.37	5.54	.014	ns
Weight (kg)																		
4	18.6	2.99	17.0	1.95	16.1	1.47	15.99	.001	1 ≠ 2; 1 ≠ 3	18.9	2.71	17.6	2.52	18.0	1.98	6.43	.002	1 ≠ 3
5	21.7	3.99	19.2	2.69	18.1	1.70	25.93	.001	1 ≠ 2; 1 ≠ 3	21.8	3.90	19.7	3.04	18.9	1.49	13.29	.001	1 ≠ 2; 1 ≠ 3
6	23.0	4.57	20.8	3.21	19.3	2.13	19.08	.001	1 ≠ 2; 1 ≠ 3	23.7	4.20	21.1	3.48	20.0	2.12	23.38	.001	1 ≠ 2; 1 ≠ 3
7	27.1	5.42	23.2	3.62	21.9	3.07	31.14	.001	1 ≠ 2; 1 ≠ 3	29.0	6.05	23.4	3.62	22.2	2.55	46.49	.001	1 ≠ 2; 1 ≠ 3
8	30.5	6.11	25.5	4.33	24.3	3.12	37.27	.001	1 = 2; 1 ≠ 3	31.8	6.79	25.6	4.70	24.5	3.92	41.89	.001	1 = 2; 1 ≠ 3
9	35.3	7.93	28.8	5.61	26.2	3.97	58.83	.001	1 ≠ 2; 1 ≠ 3	35.3	8.25	28.6	4.51	27.9	4.06	46.50	.001	1 ≠ 2; 1 ≠ 3
10	38.9	8.26	32.0	6.69	29.7	4.48	43.81	.001	1 ≠ 2; 1 ≠ 3	37.3	8.60	31.9	6.99	29.4	4.33	27.62	.001	1 ≠ 2; 1 ≠ 3
11	43.8	9.98	38.1	8.33	34.6	6.80	28.23	.001	1 ≠ 2; 1 ≠ 3	42.9	9.78	35.5	7.75	32.8	4.52	40.37	.001	1 ≠ 2; 1 ≠ 3
12	47.8	9.65	41.3	8.41	38.5	5.71	37.45	.001	1 ≠ 2; 1 ≠ 3	51.0	11.77	38.3	7.52	36.0	5.54	95.12	.001	1 ≠ 2; 1 ≠ 3
13	50.4	9.57	45.4	7.55	42.5	6.10	19.66	.001	1 ≠ 2; 1 ≠ 3	52.1	10.89	43.7	9.62	40.3	6.50	32.50	.001	1 ≠ 2; 1 ≠ 3
14	52.2	9.66	47.4	8.00	45.1	5.99	24.11	.001	1 ≠ 2; 1 ≠ 3	56.6	11.92	47.8	8.17	46.4	8.24	35.11	.001	1 ≠ 2; 1 ≠ 3
15	52.2	7.53	49.7	7.79	48.3	5.91	8.05	.001	1 ≠ 2	58.6	10.74	51.3	6.90	50.1	6.03	37.78	.001	1 ≠ 2; 1 ≠ 3
16	53.2	8.41	51.4	7.25	49.8	6.09	6.26	.001	1 ≠ 2	62.8	10.13	54.6	8.26	52.9	6.31	34.15	.001	1 ≠ 2; 1 ≠ 3
17	53.1	8.40	52.8	11.07	51.5	6.57	0.53	.588	ns	62.2	9.19	56.8	8.04	53.5	5.59	13.33	.001	1 ≠ 3; 2 ≠ 3

Abbreviation: ns, nonsignificant.

TABLE 4 Results of mean differences analysis between the three geographical areas for body mass index and waist circumference of schoolchildren from both sexes, aged 4 to 17 years

	Girls									Boys								
	Sea level		Rainforest area		High-altitude		Level altitude difference			Sea level		Rainforest area		High-altitude		Level altitude difference		
Age (years)	Mean	*SD*	Mean	*SD*	Mean	*SD*	F	*p*	Dif	Mean	*SD*	Mean	*SD*	Mean	*SD*	F	*p*	Dif
Body mass index (kg/m^2)																		
4	16.6	1.91	16.1	1.42	15.9	1.34	2.83	.061	ns	16.5	1.78	16.6	1.82	16.8	1.33	0.20	.816	ns
5	17.1	2.29	16.4	1.69	16.1	1.24	5.37	.005	ns	17.2	2.37	16.7	1.84	16.3	0.97	2.70	.070	ns
6	17.1	2.44	16.6	1.96	15.6	1.40	8.26	.001	1 ≠ 2	17.5	2.36	16.7	1.94	15.6	1.08	15.34	.001	1 ≠ 2; 2 ≠ 3
7	18.3	2.56	16.7	1.74	16.0	1.44	25.82	.001	1 ≠ 2; 1 ≠ 3	18.8	2.82	16.7	1.65	16.0	1.25	34.70	.001	1 ≠ 2; 1 ≠ 3
8	18.7	3.01	16.9	2.17	15.6	1.38	28.96	.001	1 ≠ 2; 1 ≠ 3	19.4	3.24	17.1	2.16	16.0	1.71	34.66	.001	1 ≠ 2; 1 ≠ 3
9	19.7	3.06	17.4	2.39	16.0	1.79	50.98	.001	1 ≠ 2; 1 ≠ 3	20.1	3.69	17.5	2.13	16.9	1.79	36.59	.001	1 ≠ 2; 1 ≠ 3
10	19.8	2.95	17.8	2.56	16.5	1.56	35.02	.001	1 ≠ 2; 1 ≠ 3	19.9	3.26	18.2	3.11	16.9	1.65	20.79	.001	1 ≠ 2; 2 ≠ 3
11	20.6	3.57	19.0	3.14	17.6	2.31	20.60	.001	1 ≠ 2; 1 ≠ 3	21.2	3.68	18.8	3.14	17.5	1.35	32.45	.001	1 ≠ 2; 1 ≠ 3
12	21.6	3.60	19.4	2.97	18.3	2.04	35.46	.001	1 ≠ 2; 1 ≠ 3	22.1	3.54	19.0	2.60	17.6	1.87	71.84	.001	1 ≠ 2; 1 ≠ 3
13	21.8	3.70	20.2	2.95	19.5	2.39	11.65	.001	1 ≠ 2; 1 ≠ 3	21.0	3.58	19.6	3.26	18.5	1.74	13.39	.001	1 ≠ 2
14	22.2	3.46	21.0	3.18	20.0	2.31	15.73	.001	1 ≠ 2; 1 ≠ 3	21.6	3.76	19.9	2.44	19.2	1.99	19.77	.001	1 ≠ 2; 1 ≠ 3
15	22.1	2.58	21.5	2.91	20.9	2.25	4.84	.009	ns	21.9	3.58	20.3	2.14	19.4	1.50	27.05	.001	1 ≠ 2; 1 ≠ 3
16	22.4	3.07	22.1	2.98	21.4	2.38	3.11	.046	ns	22.6	3.09	21.0	2.88	20.0	1.73	19.40	.00	1 ≠ 2; 1 ≠ 3
17	22.4	3.12	22.8	4.34	22.2	2.68	0.33	.723	ns	22.6	3.09	21.6	2.37	20.4	1.65	8.50	.001	1 ≠ 2
Waist circumference (cm)																		
4	52.5	4.66	50.9	3.04	46.3	2.79	26.32	.001	1 ≠ 2; 2 ≠ 3	52.9	4.20	52.3	3.60	49.4	3.64	7.74	.001	1 ≠ 2
5	54.1	5.74	52.4	3.54	48.4	3.25	25.07	.001	1 ≠ 2; 2 ≠ 3	54.8	5.74	53.4	4.27	49.6	2.34	15.71	.001	1 ≠ 2; 2 ≠ 3
6	54.3	5.52	54.3	4.10	51.6	3.35	6.80	.001	1 ≠ 2; 2 ≠ 3	55.9	4.90	54.9	4.28	52.9	2.96	8.15	.001	1 ≠ 2
7	57.7	6.37	55.8	4.38	53.1	3.58	13.80	.001	1 ≠ 2; 2 ≠ 3	60.7	7.70	56.1	4.08	56.0	4.56	18.70	.001	1 ≠ 2; 1 ≠ 3
8	59.7	6.93	57.1	5.22	54.7	4.09	12.70	.001	1 ≠ 2; 1 ≠ 3	63.6	7.50	58.2	5.49	56.1	4.92	28.75	.001	1 ≠ 2; 1 ≠ 3
9	63.6	8.16	59.0	5.88	56.0	4.56	33.00	.001	1 ≠ 2; 1 ≠ 3	65.8	9.32	60.0	5.43	58.4	4.93	30.13	.001	1 ≠ 2; 1 ≠ 3
10	63.8	7.08	60.4	6.26	57.8	5.13	18.37	.001	1 ≠ 2; 1 ≠ 3	65.5	8.14	62.3	6.90	59.0	4.33	17.63	.001	1 ≠ 2; 1 ≠ 3
11	65.6	7.88	63.2	6.63	60.6	6.11	11.67	.001	1 ≠ 2	69.2	8.71	64.2	7.13	60.3	4.40	30.67	.001	1 ≠ 2; 1 ≠ 3
12	66.6	7.90	64.6	6.38	62.6	5.69	10.38	.001	1 ≠ 2	73.1	9.18	64.6	5.92	61.8	5.57	75.36	.001	1 ≠ 2; 1 ≠ 3
13	68.9	8.76	66.5	6.20	65.5	6.39	4.73	.009	ns	70.0	8.86	66.5	6.99	64.1	5.21	13.71	.001	1 ≠ 2; 1 ≠ 3
14	69.5	7.41	68.1	6.30	66.5	5.57	6.61	.001	1 ≠ 2	72.6	9.46	67.5	5.18	66.4	5.58	23.70	.001	1 ≠ 2; 1 ≠ 3
15	69.9	6.22	68.8	6.75	68.3	6.09	1.74	.177	ns	73.0	7.98	68.7	4.70	68.1	4.16	24.75	.001	1 ≠ 2; 1 ≠ 3
16	69.9	7.11	70.1	6.18	69.3	6.32	0.47	.623	ns	75.9	7.43	70.7	6.21	70.2	4.65	22.17	.001	1 ≠ 2; 1 ≠ 3
17	70.0	7.18	70.8	8.11	71.0	6.04	0.35	.706	ns	75.6	6.59	71.5	6.75	70.9	4.41	7.27	.001	1 ≠ 2

Abbreviation: ns, nonsignificant.

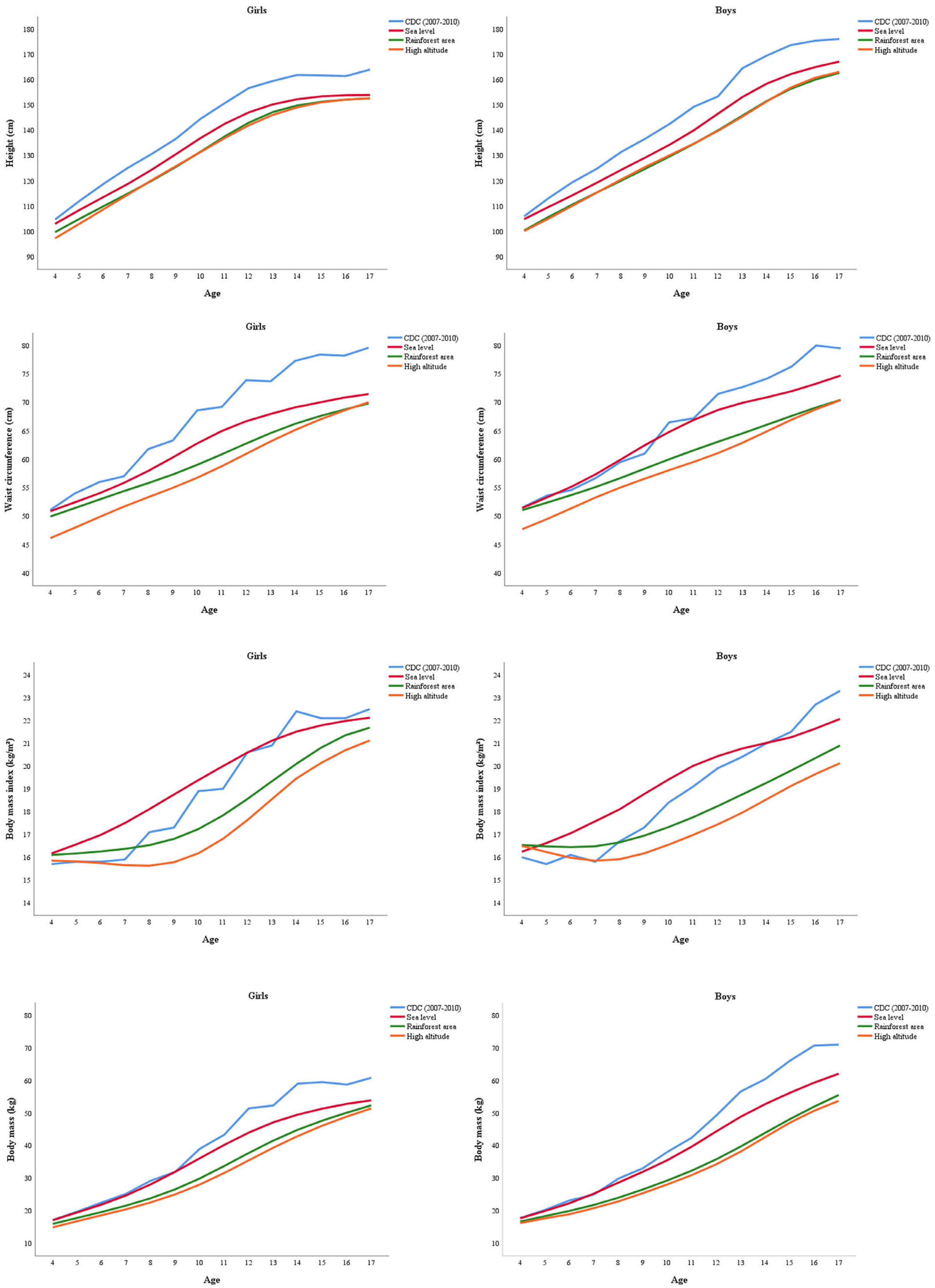

FIGURE 1 Comparison of the age and sex-specific 50th percentile values for height, weight, body mass index, and waist circumference between Peruvians boys and girls and those from Centers for Disease Control and Prevention (2007–2010 CDC) as proposed by Fryar et al. (2012)

TABLE 5 Mean z-scores and *SD* of height, weight, body mass index, and waist circumference of schoolchildren from both sexes within each site standardized relative to comparative data for Centers for Disease Control and Prevention (2007–2010 CDC)

	Boys						Girls					
	Sea level (*n* = 1189)		Rainforest area (*n* = 2026)		High-altitude (*n* = 915)		Sea level (*n* = 1347)		Rainforest area (*n* = 2275)		High-altitude (*n* = 1001)	
	z	*SD*	z	*SD*	z	*SD*	z	*SD*	z	*SD*	z	*SD*
Height	−0.64***	0.85	−1.26***	0.86	−1.34***	0.86	−0.67***	0.87	−1.15***	0.82	−1.27***	0.72
Weight	−0.15***	0.68	−0.59***	0.52	−0.74***	0.38	−0.27***	0.71	−0.62***	0.55	−0.82***	0.42
BMI	0.08[a]	0.75	−0.24***	0.61	−0.47***	0.39	−0.00[a]	0.72	−0.27***	0.58	−0.46***	0.44
WC	−0.41***	0.64	−0.55***	0.47	−0.77***	0.43	−0.47***	0.69	−0.60***	0.51	−0.83***	0.45

[a]nonsignificant.
***$p < .001$.

resources for their education, nutrition, and health (Pawson et al., 2001). It should be noted that inhabitants of high-altitude in the Andes who live in urban areas and had a better access to health and other resources were taller than rural children (Obert et al., 1994). Similar results were reported among Mexican children (Peña Reyes et al., 2003). In general, no statistically significant differences were found for height and weight between Junín (high-altitude) and Chanchamayo (rainforest area) schoolchildren in both sexes and all age intervals. Since the 17th century that there is a process of colonization of the Central Jungle that allows the establishment of *haciendas* for the production of sugar cane and coca. At the beginning of the 19th century, a gradual transition from the production of cane sugar to coffee was established, which generates demographic growth due to the need for labor. In the last seven decades, the economy has diversified with citrus production and cattle raising. Therefore, the socioeconomic and environmental conditions of La Merced and San Ramón have improved substantially allowing its population better and more abundant nutritional resources, as well as greater health care coverage (INEI, 2018). These facts explain the slight growth advantages shown by children residing in the rainforest, since variation in environmental conditions per se, access to nutritional resources, and/or context-specific socioeconomic conditions may contribute to the differences observed in the state of growth (de Meer et al., 1993; Leonard et al., 1990).

Our data show that children living at sea level had higher BMI values than their peers in the rainforest area and high-altitude (between 6 and 14 years in girls and between 6 and 17 years in boys). When compared with those from Marquiri and Tintaya communities, which were calculated on the basis of weight and height values reported by Pawson and Huicho (2010), Junín (high-altitude) boys had slightly higher BMI values (~0.41 kg/m^2) than the Marquiri, but similar to Tintaya (~0.01 kg/m^2); on the other hand, girls presented slightly higher values than the Marquiri (~0.18 kg/m^2) and displayed lower values than the Tintaya (~0.27 kg/m^2). The effects of nutritional and epidemiological transitions occurring in recent years in Peru may explain the differences found in BMI among the samples. These changes had a greater impact in the cities on the Peruvian coast and were characterized by lifestyle and eating pattern changes that resulted in a higher prevalence of overweight and obesity (Bustamante & Maia, 2013). For example, the results found in children between 5 and 9 years in the National Household Survey (ENAHO) indicated that the inhabitants of the coast had a higher prevalence of overweight/obesity compared with those of the high-altitude and rainforest areas (30.8%, 14.8%, and 14.2%, respectively) (Álvarez-Dongo et al., 2012).

Schoolchildren living at sea level showed higher WC values than those living at high-altitude and in the rainforest. In recent years, the WC has been considered a suitable anthropometric marker of central obesity and has also been associated with risk factors in adults (Després et al., 2008; Eisenmann, 2005). In all age intervals and in the three geographic regions, boys had higher values than girls. Again, the socioeconomic condition is an important factor that may explain these differences, given that the city of Barranco (sea level) is wealthier when compared with Junín (high-altitude) and Chanchamayo (rainforest area), allowing schoolchildren to have greater access to education, nutrition and health services (INEI, 2018). However, these better socioeconomic and environmental life conditions were also linked to the adoption of sedentary lifestyles and inappropriate nutritional habits which are inevitably associated with increases in overweight/obesity, in addition to WC (Bustamante & Maia, 2013).

In answering our second aim, we found important differences, in terms of their position relative to the 50th percentile as well as in z-means, between the CDC and the Peruvian reference data. Those living at different altitudes are systematically shorter, lighter, and have lower BMI (except for children living at sea level from 4 to 14 years) and WC than their American peers. In interpreting these results, it is important to consider CDC and Peru distinct sampling size and structure, as well as ethnic origins. The CDC growth reference has data from the years 2007–2010 related to surveys conducted at different time periods comprising healthy children and adolescents; all were exposed to contextual conditions that apparently enhanced their growth and development without environmental insults to their genetic potential (Fryar et al., 2012). In contrast, the Peruvian sample included youth from different regions, characterized by inequalities in the distribution of, and access to, economic, educational, nutritional, and health resources (INEI, 2018). Hence, deficiencies in public health care, problems of subsistent nutritional deficits most probably linked to deficits in basic infrastructure associated with relatively low education levels, can play important roles in explaining the lower values in their growth indicators compared with American schoolchildren. These issues also reflect the lower developmental indexes, namely, demography, social and health support, family income, education and culture, employment, and economic activity relative to US. On the other hand, it should be considered that comparisons between studies can also be influenced by different measurement techniques used and lack of standardization, such as WC values, due to the absence of consensus on the ideal anatomical location for this measurement (Ross et al., 2008).

The present study provides a unique body of data regarding regional variation (sea level, rainforest, and high-altitude) between children and adolescents from public schools in the central region of Peru. Notwithstanding its relevance, three limitations have to be highlighted. First, despite its large sample size, it is not representative of the overall population of Peruvian schoolchildren, which limits the generalization of the results. Second, the cross-sectional design does not allow a dynamic analysis of intraindividual changes and interindividual differences occurring during the growth period as a result of complex interactions between biological and environmental factors. Third, comparisons between our results and the CDC references should be carefully interpreted because of sample differences in terms of biological and environmental features. Still, the CDC references are considered a valuable tool in clinical practice not only for screening children and adolescents' physical growth but also for population contrasts.

In conclusion, Peruvians living at sea level were taller, heavier, and had greater BMI and WC compared with their peers living at high-altitude and in the rainforest; however, there were no substantial differences in adolescents' growth indicators from these two different areas. Peruvian schoolchildren of both sexes from the three geographical areas were shorter and lighter than their American peers. Boys and girls living in the rainforest and at high-altitude had lower BMI, whereas WC values of American schoolchildren are higher than those of their specific Peruvian peers by age and gender.

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CONFLICT OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

AUTHOR CONTRIBUTIONS

Alcibíades Bustamante: Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); writing – original draft (equal). **Carla Santos:** Conceptualization (equal); formal analysis (equal); investigation (equal); methodology (equal); writing – original draft (equal). **Sara Pereira:** Conceptualization (equal); formal analysis (equal); investigation (equal); methodology (equal); writing – original draft (equal). **Duarte Freitas:** Writing – review and editing (equal). **Peter T. Katzmarzyk:** Writing – review and editing (equal). **José Maia:** Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); supervision (equal); validation (equal); visualization (equal); writing – original draft (equal).

DATA AVAILABILITY STATEMENT

The data sets generated and analyzed during the current study are not publicly available due to privacy laws associated with children's data but are available with a data-sharing agreement as approved by the ethics committee of the National University of Education Enrique Guzmán y Valle, Lima, Peru.

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