RBCDH Brazilian Journal of KINANTHROPOMETRY and Human Performance

DOI: http://dx.doi.org/10.5007/1980-0037.2012v14n6p690

original article

Assessment of physical growth through body proportionality in Peruvian children living at moderately elevated altitudes

Valoración del crecimiento físico por medio de la proporcionalidad corporal en escolares peruanos que viven a moderada altitud

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Abstract – The strategy of our approach involves the use of an instrument for measuring body proportionality for the purpose of comparing growth of segments to body dimensions. The objective of this descriptive transversal study is to assess physical growth through body proportionality of school children, aged 6 to 12 years, living at moderately elevated altitudes. Study participants included 482 females and 473 males ranging in ages from 6 to 12 years and possessing middle socioeconomic status. The students were selected from a stratified probability segment of 6,659 students. In all, we evaluated: anthropometric measurements of weight (kg), height (m), five skinfolds (mm), four body perimeters and four body-bone diameters. Proportionality analyses were performed using the Phantom theoretical model proposed by Ross and Wilson (1974). The results of the Phantom Z-scores for both genders show generally negative values for body weight (-3.7 to -1.7), skinfold thickness (0.5 to -1.5), and body circumference (-0.9 to -1.3). In turn, bone diameters show positive values in all ages as well as in both genders (1.0 to 3.2). The results suggest that school children living at moderately elevated altitudes are characterized by slow growth correlated to body weight; on the other hand, skinfold thicknesses and body circumferences in relation to bone diameters exhibit a tendency to robustness.

Key words: Altitude; Growth; Proportionality; School children.

Resumen – *La estrategia del Phantom es un instrumento para medir la proporcionalidad corporal que permite comparar el crecimiento de los segmentos y dimensiones corporales. El objetivo del presente estudio radica en valorar el crecimiento físico por medio de la proporcionalidad corporal de escolares de 6 a 12 años que viven a moderada altitud. El estudio es de tipo descriptivo Transversal. Participaron de la investigación 482 damas y 473 varones de 6 a 12 años de condición socioeconómica media. Los escolares fueron seleccionados de forma probabilística estratificada de un total de 6659 alumnos. Se evaluó las medidas antropométricas de peso (kg), estatura (m), cinco pliegues cutáneos (mm), cuatro circunferencias corporales y cuatro diámetros óseos. El análisis de la proporcionalidad se efectuó por medio del modelo teórico del Phantom propuesto por Ross y Wilson (1974). Los resultados del Z-escore del Phantom para ambos géneros muestran valores negativos de forma general para el peso corporal (-3,7 a -1,7), pliegues cutáneos (0,5 a -1,5) y circunferencias corporales (-0,9 a -1,3). A su vez, los diámetros óseos evidencian valores positivos en todas las edades y en ambos géneros (1,0 a 3,2). Los resultados sugieren que los escolares de moderada altitud se caracterizan por presentar un lento crecimiento respecto al peso corporal, pliegues cutáneos y circunferencias corporales y en relación a los diámetros óseos muestran una tendencia a la robustez.*

Palabras clave: *Altitud; Escolares; Crecimiento; Proporcionalidad.*

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Received: 21 January 2012
Accepted: 17 July 2012

INTRODUCTION

Physical growth was classically defined by Meredith[1] as the sequence of somatic modifications which a biologic organism undergoes during its ontogenetic history or, alternatively, as the entire series of anatomic and physiologic changes taking place between the beginning of prenatal life and the close of senility. This process constitutes a chain of phenomena of cellular, physiological and morphological order that are genetically predetermined and can be modified by phenomena occurring in the environment[2]. For its assessment, growth chart standards are necessary. In fact, height and body weight are the most common parameters to assess physical growth and nutritional status in children and adolescents, regardless of geographical region, although the assessment of fat and muscle areas may possibly provide a better interpretation of physical growth and body composition[3]. In this sense, anthropometric variables are accepted as important tools for the health control and nutritional assessment of children[4], besides enabling to assess the impact of environmental and genetic factors on the biological adaptation of human populations, both at sea level and at high altitudes[2].

Thus, several studies have been developed in high-altitude regions[5-7], for which WHO and NCHS reference standards were used to analyze physical growth in children and adolescents.

However, it should be highlighted that, surprisingly, there were no national and international studies on the use and application of the Phantom stratagem for the assessment and follow-up of physical growth in children and adolescents living at moderate to high altitudes, because, in fact, proportionality is considered as an area of kinanthropometry, along with body composition and somatotype. Therefore, its importance resides in differentiating specific groups[8], which helps to predict immediately the possibility of success in several sports and to analyze of similarities and differences between athletes[9] and non-athletes; additionally, the unisex Phantom model is an ambitious attempt to compare the growth of the dimension of body segments, both within a population and between populations[10], which would enable to determine maturity capability in function of an arbitrary adult height. On the other hand, some studies pointed out that environmental conditions influence the development of body proportions of children and adolescents living under stressful hypoxic conditions[5-7]. Such studies used reference standards that usually assess weight and height. In this sense, Carter and Ackland[11] warn about the need to control the bias produced when working with absolute measurements in morphological studies, and recommend the application of analytical methods such as proportionality. From this perspective, the Phantom stratagem provides a more detailed description and analysis of body proportions, enabling the quantification of differences in proportionality[12]. Thus, the aim of the present study was to assess physical growth through body proportionality in school children aged 6 to 12 years living at moderately high altitudes.

METHODS

Type of study

This research employed a descriptive cross-sectional design to study school children of both sexes aged 6 to 12 years, attending the primary level of basic education in the Peruvian educational system. In Peru, basic education comprises three levels: Early Education (3-6 years), Primary School (6-12 years), and Secondary School (12-16 years). All the children in the study were enrolled in public schools in the urban area of the district of José Luis Bustamante y Rivero from the province of Arequipa, Peru. This district is located 2320 meters above sea level, which is considered as a moderately high altitude[13].

Sample

Four public educational centers from the district of José Luis Bustamante y Rivero were intentionally selected for the study. The universe included a total of 6659 students belonging to the middle socioeconomic status, 3300 males and 3359 females. To calculate sample size, we considered the most unfavorable hypothesis (0.50), with a precision of (0.05) for a 95% confidence interval (95%CI), and the optimal sample size was 955 subjects (14.34%), 473 males and 482 females, respectively.

To determine middle socioeconomic status, a questionnaire proposed by Cossio-Bolaños[14] was applied, which includes 7 questions that enable to identify children belonging to the middle socioeconomic status through a scale ranging from 12 to 75 points, in which values ≤35 points indicate low status, between 35-59 points indicate middle status, and ≥ 60 points determine high status. In this sense, Peruvian children and adolescents attending schools from marginal urban areas usually belong to the low socioeconomic status, and those living in high-altitude rural areas belong to the very low status.

To understand the socio-cultural reality in Peru, it is necessary to understand the autochthonous cultural diversity influenced by the constant miscegenation with the European Western culture, as well as by the contribution of important migration flows, especially from the Far East and the Sub-Saharan Africa. In this sense, the ethnic structure of the study sample is considered mixed, since the main language that students use to communicate with family and their social network is Spanish. In turn, the last name of the studied children was considered a second indicator, and the overall sample had a mixture of last names of Amerindian (indigenous) and Caucasian origin. According to The World Fact Book periodical[15], of the American Central Intelligence Agency, 45% of the Peruvian population were Amerindians, 37% were *mestizos* (mixed Amerindian and white), 15% were white, and 3% had African, Japanese or Chinese descent. The protocol of the present investigation was approved by the ethics committee of the Instituto del Deporte Universitario (IDUNSA) of Universidad Nacional de San Agustín, Arequipa, under number 002-2009.

Procedures

Age group was defined by the student's birth records, which was provided by each educational center, along with the approval for data collection and the respective consent by the principals of each institution.

All parents and/or guardians of the children were informed on the purpose of the study and the procedures to be performed. In order to do that, a written and informed consent was drawn, allowing for the collection of anthropometric measurements in the school children.

For the assessment of anthropometric variables, the guidelines and suggestions proposed by the International Society for the Advancement of Kinanthropometry (ISAK) were adopted[16]. The measurements taken were the following: body mass (kg), measured with a Tanita digital scale; height (m), measured using a Seca aluminum stadiometer; body circumferences (cm), assessed using a nylon measuring tape (Seca), including the circumferences of the right arm in relaxed position, of the chest between inhalation and exhalation (mesosternal region), of the hip (at the height of the greater trochanter) and of medial calf; skin folds (mm), considering triceps, subscapular, suprailiac, abdominal and medial calf skinfold thickness, assessed using a Harpenden caliper; bone diameters (cm), measured using a Seca pachymeter to assess the diameter of the bones bistyloid at the wrist, biepicondylar at the elbow, femoral biepicondylar, and bimalleolar at the ankle.

To assess proportionality, we used the Phantom stratagem, designed by Ross and Wilson[17] and revised by Ross and Ward[12].

This stratagem is based on a unisex human reference model to develop a calculation device designed to quantify the proportional differences[17]. Phantom results are expressed as Z-score values, implying an increase or reduction for the anthropometric variable assessed, in which Z-scores can be positive, meaning that the subject or sample is proportionally larger than the Phantom model, or negative, meaning that the element is proportionally smaller than the Phantom model.

Quality of the measurements

All anthropometric variables were assessed twice, with the purpose of ensuring and proving a better quality to the measurements. This procedure was applied to every 10 subjects, totaling 45 girls and 45 boys. All measurements were taken by the same examiner, who was highly trained and had a level 3 ISAK certification. The technical error of the anthropometric variables oscillated between 1 and 3% and the reproducibility coefficient ranged between 0.85 and 0.99, respectively.

Statistical analysis

Normal distribution of the sample was assessed by the Kolmogorov-Smirnov normality test. The anthropometric variables were characterized by descriptive statistics as arithmetic means (X) and standard deviations (SD). Comparisons between genders were performed using the "t" test for independent samples ($p<0.05$), and age groups were compared using two-way ANOVA ($p<0.05$). The proportionality of physical growth variables were assessed using Phantom Z-scores, as proposed by Ross and Wilson[17]. The statistical data were processed with Excel spreadsheets and the statistical software Sigma Estat, 8.0.

RESULTS

Table 1 shows the anthropometric characteristics of Peruvian school children living at moderately high altitudes, expressed as mean and standard deviation. The values for body weight, height, five skinfolds, four bone diameters, and four body circumferences are expressed as absolute values. An increase in mean values was observed as age advances in both genders.

Children of both genders exhibited similar behavior in regard to weight and height from 6 to 12 years, with girls having slightly higher values than boys.

As for skinfold thickness, girls showed a higher amount of fat tissue in the 5 skin folds; however, no significant differences were found in bone diameters, since similar values were observed in both genders until 12 years of age. In the case of arm, chest and calf circumferences, mean values were similar until 12 years of age. In turn, hip circumference was similar until 9 years of age; afterwards, girls presented higher values than boys.

Body weight values, expressed as Phantom Z-scores, are depicted in figure 1. The results showed negative values for all age groups and for both genders. In fact, Z-scores of the studied children revealed lower body weight in comparison with the Phantom theoretical model; in turn, it was observed a trend of increase as age advances until 12 years, when it comes closer to the adult model. In general, girls showed higher body weight in all age groups compared with boys.

The values for skinfold thickness, expressed as Phantom Z-scores, are depicted in figure 2. The results revealed that girls showed positive values for triceps skinfold thickness from 6 to 12 years of age and negative values for the remaining skinfold thicknesses at all ages; however, the same behavior was not observed in boys, especially considering triceps skinfold thickness, since, contrary to girls, the five skinfold thicknesses (including triceps skinfold thickness) showed negative values compared with those of the Phantom theoretical model. Thus, girls had higher adiposity than boys in all age groups. In turn, figure 2 shows an increase in the amount of fat tissue among school children of both genders, more accelerated in girls and slower in boys, since 12-year-old girls showed values almost similar to those of the Phantom theoretical model; however, this phenomenon seems to be somewhat delayed in boys, and would be evidenced at later ages.

Table 1. Physical growth variables of Peruvian school children living at moderately high altitudes.

Variables	6 years		7 years		8 years		9 years		10 years		11 years		12 años	
	boys	girls	boys	girls	boys	girls	boys	girls	boys	girls	boys	girls	boys	girls
	(n=56)	(n=80)	(n=67)	(n=61)	(n=68)	(n=63)	(n=73)	(n=58)	(n=59)	(n=63)	(n=71)	(n=76)	(n=79)	(n=81)
Body Mass (kg)	21.81 (2.24)	22.48 (2.62)*	22.91 (3.92)	24.62 (3.45)*	25.88 (3.55)	26.57 (3.04)*	29.38 (3.80)	30.38 (4.62)*	33.25 (4.05)	37.2 (5.37)*	37.01 (4.83)	38.92 (5.96)*	42.04 (6.32)	43.67 (5.12)*
Height (m)	1.14 (0.05)	1.19 (0.05)	1.18 (0.05)	1.23 (0.04)	1.25 (0.05)	1.26 (0.06)	1.28 (0.04)	1.32 (0.06)	1.36 (0.07)	1.4 (0.06)	1.43 (0.05)	1.44 (0.05)	1.47 (0.07)	1.51 (0.05)
Skinfold thicknesses (mm)														
Triceps	9.01 (1.99)	10.53 (2.17)*	9.03 (2.70)	11.38 (2.96)*	9.29 (2.50)	12.09 (2.08)*	9.55 (3.10)	13.1 (2.09)*	10.81 (2.22)	13.11 (3.15)*	11.58 (2.68)	13.56 (2.91)*	11.08 (3.69)	15.61 (3.26)*
Subscapular	5.4 (1.08)	6.96 (2.30)*	5.7 (1.76)	7.58 (2.77)*	5.91 (1.64)	9.11 (2.08)*	6.95 (2.49)	9.88 (2.69)*	7.52 (2.49)	9.17 (2.90)*	7.78 (2.94)	11.33 (3.69)*	8.19 (2.76)	13.57 (3.36)*
Suprailiac	6.64 (1.89)	8.73 (3.18)*	7.24 (3.94)	8.94 (3.39)*	8.25 (4.13)	9.34 (2.24)*	8.32 (4.30)	11.86 (3.34)*	10.77 (4.16)	9.99 (3.77)*	9.68 (5.25)	12.93 (5.19)*	11.44 (6.28)	17.27 (4.02)*
Abdominal	6.54 (1.89)	9.42 (3.04)*	7.78 (3.53)	10.02 (3.72)*	8.30 (3.45)	11.40 (2.91)*	8.97 (4.35)	12.49 (3.75)*	12 (4.13)	14.24 (3.95)*	11.94 (6.29)	13.73 (5.79)*	13.12 (7.77)	17.62 (4.90)*
Calf	8.11 (2.12)	9.56 (2.05)*	7.69 (2.88)	9.90 (2.08)*	7.91 (2.41)	10.22 (2.27)*	8.71 (2.89)	11.07 (2.58)*	10.46 (2.06)	11.69 (2.45)*	10.33 (2.93)	13.11 (3.11)*	10.36 (3.68)	14.77 (2.30)*
Diameters (cm)														
Elbow	4.99 (0.25)	5.08 (0.27)	5.16 (0.31)	5.13 (0.34)	5.32 (0.35)	5.27 (0.29)	5.51 (0.30)	5.37 (0.48)	5.85 (0.44)	5.98 (0.35)	5.95 (0.51)	5.69 (0.49)	6.4 (0.47)	6.10 (0.29)
Wrist	4.23 (0.23)	4.13 (0.19)	4.40 (0.20)	4.39 (0.65)	4.59 (0.25)	4.53 (0.40)	4.64 (0.23)	4.61 (0.35)	4.91 (0.37)	5.00 (0.40)	4.99 (0.44)	4.89 (0.23)	5.37 (0.31)	5.32 (0.64)
Knee	7.51 (0.42)	7.47 (0.40)	7.81 (0.46)	7.60 (0.37)	8.07 (0.38)	7.88 (0.38)	8.23 (0.52)	7.9 (0.54)	8.75 (0.46)	8.67 (0.52)	8.81 (0.60)	8.51 (1.02)	9.46 (0.59)	8.87 (0.84)
Ankle	5.36 (0.55)	5.27 (0.26)	5.44 (0.35)	5.36 (0.40)	5.79 (0.44)	5.67 (0.40)	5.93 (0.43)	5.81 (0.63)	6.06 (0.40)	6.18 (0.61)	6.26 (0.41)	6.1 (0.36)	6.67 (0.45)	6.83 (2.17)
Circumferences (cm)														
Arm	16.70 (1.08)	17.00 (1.10)	17.23 (1.37)	17.40 (1.51)	17.49 (0.43)	17.64 (1.08)	18.07 (1.27)	18.59 (1.81)	19.03 (1.06)	19.54 (1.84)	19.91 (2.29)	20.45 (2.50)	21.18 (1.82)	21.84 (1.58)
Chest	59.33 (2.51)	59.56 (3.39)	61.89 (4.44)	61.61 (3.84)	63.14 (3.38)	64.67 (3.33)	64.52 (2.77)	66.03 (5.04)	69.33 (3.97)	69.13 (4.64)	69.18 (4.98)	71.95 (5.63)	73.59 (5.37)	75.16 (5.50)
Hip	61.13 (3.47)	63.31 (3.20)	62.69 (4.29)	64.39 (4.49)	65.45 (4.13)	66.51 (3.89)	67.9 (4.86)	69.66 (6.14)	70.53 (5.22)	75.87 (5.68)*	74.10 (4.73)	76.18 (6.46)*	78.68 (5.18)	82.47 (4.66)*
Calf	23.10 (2.41)	23.26 (1.22)	23.35 (1.68)	24.06 (0.99)	24.21 (1.94)	24.51 (1.54)	25.63 (1.53)	25.69 (1.89)	27.78 (4.15)	27.40 (2.59)	27.74 (3.84)	28.28 (3.97)	29.70 (2.16)	29.44 (2.39)

* $p<0.05$. Significant difference in regard to girls from the same age group.

Therefore, in general, both boys and girls had fat tissue values lower than those of the Phantom model, which lead us to interpret that this sample comprises students with thin features, low adiposity levels and a trend of increase in skinfold thicknesses during late adolescence.

Phantom Z-scores for bone diameters are depicted in figure 3. For both genders and in all age groups, results showed positive values from 6 to 12 years of age. These results point out that the children in the present study had a larger build in the four body diameters compared with the Phantom theoretical model. In this sense, both boys and girls showed a thick build in all age groups, with the bistyloid diameter at the wrist being the one that presented higher breadth (thickness) compared with the Phantom theoretical model. Therefore, the behavior of body diameters throughout age groups was similar for both genders, remaining relatively stable at least until 12 years of age.

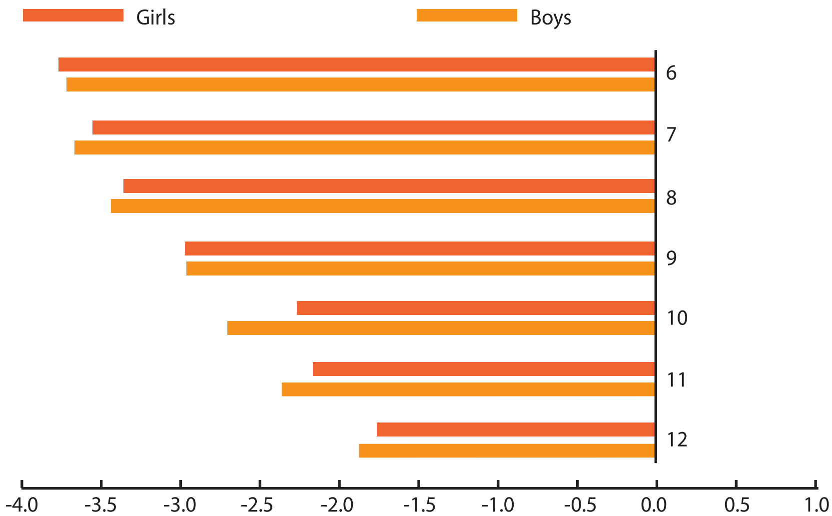

Figure 1. Body weight values for Peruvian school children living at moderately high altitudes, expressed as Phantom Z-scores.

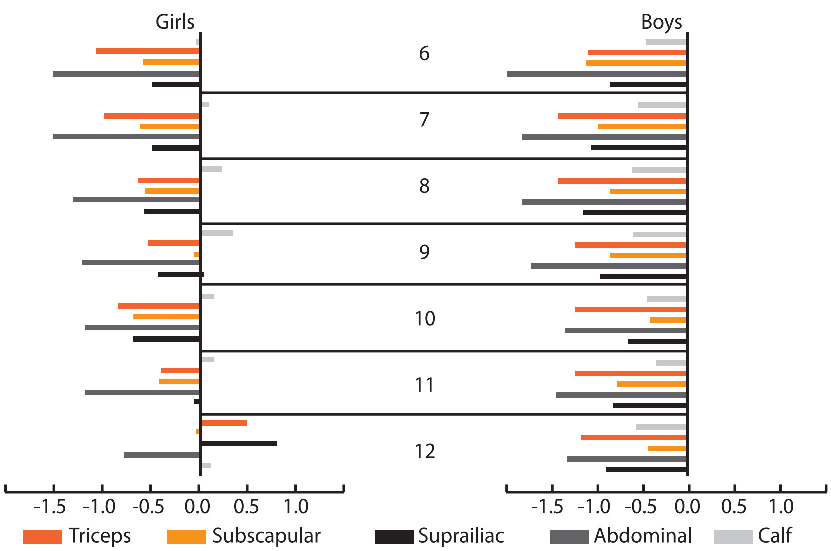

Figure 2. Skinfold values for Peruvian school children living at moderately high altitudes, expressed as Phantom Z-scores.

The values for body circumferences, expressed as Phantom Z-scores, are depicted in figure 4. The results point out that both girls and boys showed negative values for body circumferences compared with the Phantom model, except for chest circumference in boys, which presented positive values. In this sense, in general, the school children studied were predominantly thin, with a trend to reach Phantom Z-score values at future ages (late adolescence). In turn, it can be highlighted that the values for body circumferences exhibited similar behavior among students of both genders.

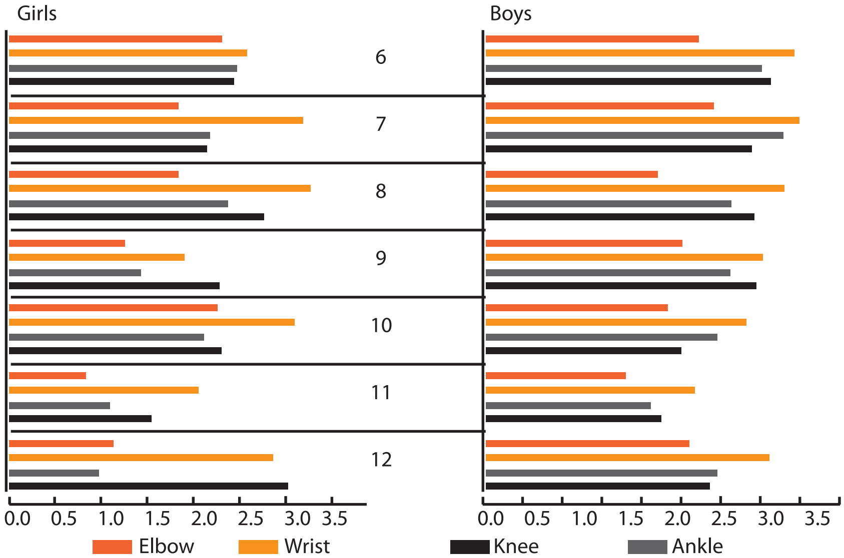

Figure 3. Values for bone diameters of Peruvian students living at moderately high altitudes, expressed as Phantom Z-scores "Phantom".

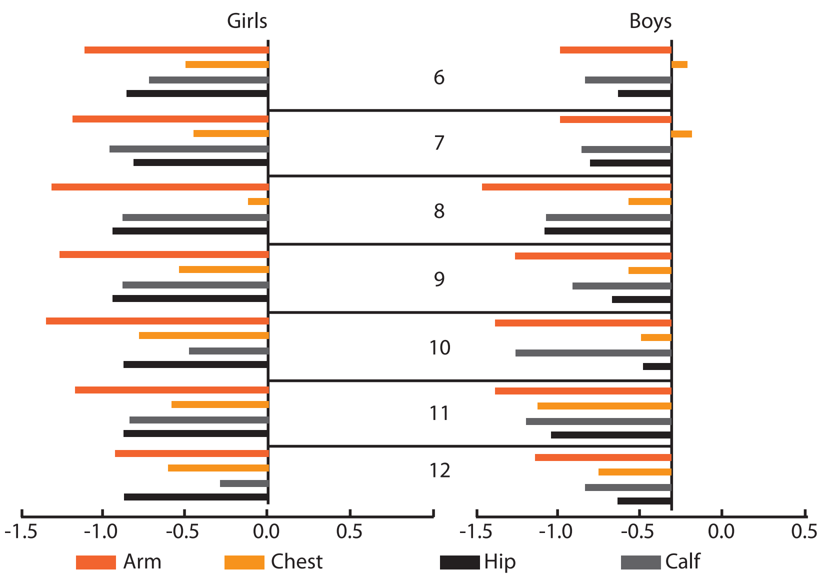

Figure 4. Values for body circumferences of Peruvian school children living at moderately high altitudes, expressed as Phantom Z-scores.

DISCUSSION

Anthropometric characteristics undoubtedly provide a unique wealth of information that can be useful to analyze body size, somatotype, body composition, and proportionality in children, adolescents and adults. In this sense, the use of the Phantom stratagem enabled to determine changes in the body proportions of students living at moderately high altitudes, since, while height increases with age, some proportions do not, and others remain relatively constant from 6 to 12 years of age. Therefore, the Phantom model is a useful tool in anthropometric studies for the comparison of the same individual, between individuals, between means for a group and an individual, and between means of two samples[18].

Body weight

The absolute values for body weight and height increased with age in both genders until 12 years of age, similarly to other international studies at sea level[19,20] and including at high altitudes[5,7], in which an increasing growth is observed as age advances; in turn, girls presented higher body weight and slightly higher height than boys in all age groups. As for Phantom Z-scores, results showed negative values for both genders and also revealed a trend of increase in weight as age advances, in which girls had higher body weight than boys from 6 to 12 years of age. This pattern of sexual dimorphism, observed in the present study, can be considered as an example of early dimorphism, since Pucciarelli et al[21] consider two types of sexual dimorphism: early and delayed, the first manifesting at pre-pubertal stages and the latter at pubertal stages. Shephard et al.[10] consider that this phenomenon is probably due to a progressive and higher subcutaneous fat accumulation observed since the first years of primary school and that, according to Tanner[22], is attributable to genetic and hormonal factors. However, one cannot rule out the possibility that cultural factors might be involved in the higher values found among girls. In turn, body weight expressed as Phantom Z-scores tends to come closer to adult body weight as chronological age advances; hence, Ross and Ward[12] consider that overall growth pattern come closer to that of adults. However, this fact is not observed yet in the sample of children living at moderately high altitudes, which suggests that this approximation occurs at future ages.

On the other hand, compared with the absolute values established by the WHO[23], school children of both genders from the present study show higher body weight, which could possibly indicate overweight in this sample. However, the positive values observed in bone diameters allow to state the possibility that students present higher bone weight, which could partially explain the higher body weight in both genders. In turn, negative values for fat tissue could reveal low fat mass levels. Therefore, excessive body weight might be determined by the higher bone weight and not by excessive body fat, which is usually present in obese children and adolescents due to genetic factors, physical inactivity, and eating patterns[24]. Consequently, although body weight was not fragmented into body compartments in this investigation, this should not be considered as a limitation of the study, since the positive values for body diameter proportionality show a clear superiority of robustness with regard to the Phantom theoretical model.

Skinfold thickness

In general terms, the girls in the present study had a higher amount of fat tissue than boys, both in absolute values and in Phantom Z-scores from 6 to 12 years of age. In this sense, the literature describes similar adiposity levels during all childhood for both genders[25], following analogous growth patterns. However, the magnitude and the timing of the changes are usually observed from the beginning of adolescence onwards and subsequently in adulthood. In turn, it was found in this study that both girls and boys show negative values for all skinfolds, except for triceps skinfold thickness, in which girls had positive values for Phantom Z-scores. The dimorphism found in the study may be attributable, according to Tanner[22], to adaptive processes achieved mainly by a better growth canalization in women, since they retain energetic reserves, as shown by the skinfolds assessed. Therefore, women are less prone to deviate from normal growth patterns compared with men[17].

On the other hand, with regard to the negative values observed for skinfold thickness, both in girls and in boys, the Phantom theoretical model indicates that the school children were characterized by being thin. In turn, as height grows in function of chronological age, skinfold thicknesses shows a trend of increase in the amount of fat tissue, which was more accelerated in girls and slower in boys; since 12-year-old girls showed values almost similar to the Phantom theoretical model and boys would show this trend at future ages. Therefore, according to the overall growth pattern, Ross and Ward[26] consider that 12-year-old children come closer to Phantom values and reach body proportions similar to those found in adulthood. Hence, the fact that boys did not come closer to Phantom values at 12 years of age could be explained by the effects produced by the altitude, since results suggest that the phenomenon of hypoxia would delay the growth of skinfolds in boys. However, nutritional factors might be involved and act in interaction during the process of growth and development. Therefore, as previously observed, growth rates are more sensitive to environmental changes in boys than in girls[27].

Body diameters

Physical growth and biological maturation are affected by several factors that act independently or in concert to modify the genetic potential of a child. In this sense, altitude seems to have no effect on bone diameters, since Phantom Z-scores showed positive values for all bone diameters, both in boys and in girls. These results reveal a high tendency to robustness among school children from Arequipa, who live at 2320 meters above sea level, since, while height increased with age, bone diameters remained relatively stable until 12 years of age. This fact may seem to be related to ethnic factors, since Eveleth and Micozzi[28] point out that *mestizos* from Peru, Bolivia, Guatemala and Mexico are generally robust and short, which would partially explain the results obtained. Although Shepard et al[10] warned that the Phantom model should be used with caution to infer ethnic differences and other kind of differences, but it can help to identify differences in growth patterns among children and adolescents without establishing a sex as a reference standard. In this sense, boys had relatively higher values than girls in all bone diameters. This fact would indicate a small dimorphic difference among both genders. However, in general, these differences are usually observed during adolescence, when girls are characteristically thinner than boys[26]. Therefore, further studies are needed to elucidate the reasons why bone diameters were proportionally larger compared with the Phantom theoretical model and remained relatively stable, by, for example, extending age range and improving variables related to length, with the purpose of better explaining bone growth (in diameter and length) in students living at moderate and highs altitudes.

Body circumferences

The Andean high plateau has long been a focus of research on the adaptation to altitude due to several reasons, including its relative accessibility, the species that flourish in the region, the presence of indigenous peoples, and early participation in the countryside[29]. In this sense, findings at high altitudes, in regard to variables that encompass body proportions assessed in absolute terms, indicate that children have a prolonged period of delayed growth, usually showing higher chest and calf circumference, higher lung capacity, and relatively low skinfold values compared with those living at sea level[5,30]. In fact, in the present study, the use of the Phantom theoretical model resulted in negative values for body circumferences in both genders, except for boys aged 7 and 8 years, who presented positive values for chest circumference. This allows to point out that school children from Arequipa, who live at moderately high altitudes, show a small growth pattern in regard to body circumferences, since, while height increases with chronological age, body circumferences remain relatively stable until 12 years of age, both in girls and in boys, which lead us to predict that circumferences could reach adult values at later ages. These findings might be attributable to the effects of hypoxia on physical growth, as previously observed for skinfold thicknesses. Therefore, the sexual dimorphism pattern in circumferences could be observed later during adolescence. In turn, the small circumference proportions observed with the Phantom model might probably be similar to the adult model after 12 years of age, which would somehow confirm a small delay in body circumferences. On the other hand, one cannot rule out the possibility that eating habits may also affect the results obtained; thus, we suggest to conduct further studies in school children living at moderately to high altitudes.

In short, the lack of control of nutritional status, eating habits, physical activity levels, and biological maturity could generate bias in the study results; for this reason, they are generally considered as possible limitations, which should be taken into account during the analysis of results; even the type of validity (internal) of the Phantom model can be a matter of debate, although it is not a consistent reason not to use this stratagem. Therefore, we suggest that such variables should be controlled in future investigations, with the purpose of generalizing the results to other latitudes with similar characteristics to those of the present study.

CONCLUSIONS

Through the use of the Phantom stratagem, results suggest that school children living at moderately high altitudes are characterized by slow growth correlated to body weight, skinfold thicknesses, and body circumferences, which could be directly associated with altitude; on the other hand, the positive values observed for bone diameters allow us to characterize the school children living at moderately high altitudes as robust (thick build).

REFERENCES

1. Meredith HV. Toward a working concept of physical growth. Am J Orthodon Oral Surg 1945;31:440-58.
2. Cossio-Bolaños MA, De Arruda M, Núñez Álvarez V, Lancho Alonso JL. Efectos de la altitud sobre el crecimiento físico en niños y adolescentes. Rev Andal Med Deporte 2011;4 (2):71-6
3. Malina RM. Ratios and derived indicators in the assessment of nutritional status. In: Himes JH, editor. Anthropometric Assessment of Nutritional Status. New York: Wiley-Liss 1991. p. 151-171.
4. Onis M, Habicht JD. Anthropometric reference data for international use; recommendations from a world health organization expert committee. Am J Clin Nutr 1996;64:650-8.
5. Frisancho AR, Baker PT. Altitude and growth – A study of the pattern of physical growth of a high altitude Peruvian Quechua population. Am J Phys Anthropol 1970; 32:279-92.
6. Stinson S. The physical growth of high altitude Bolivian Aymara children. Am J Phys Anthropol 1980;52 (3):377-85.
7. Pawson I, Huicho L, Muro M, Pacheco A. Growth of children in two economically diverse Peruvian high-altitude communities. Am J Hum Biol 2001;13 (3):323-40.
8. Ross WD, Marfell-Jones MJ. Kinanthropometry. In: McDougall JD, Weuger HA, Green HJ, Physiological testing of the high performance athlete. Champaign: Human Kinetics Books. 1991. p.223-308.
9. Ackland TR, Schreiner AB, Kerr DA. Absolute size and proportionality characteristics of World Championship female basketball players. J Sports Sci 1997;15:485-90.
10. Shephard RJ, Labarre R, Jéquier JC, Lavallee H, Rajic M, Volle M. The "Unisex Phantom," Sexual Dimorphism, and Proportional Growth Assessment. Am J Phys Anthropol 1985;67:403-12

11. Carter JEL, Ackland TR. Sexual dimorphism in the physiques of world championship divers. J Sport Sci 1998;6 (4):317-329.
12. Ross WD, Ward R. Human Proportionality and Sexual Dimorphism. In: Hall RL. editor. Sexual dimorphism in homo sapiens: a question of size. New York: Praeger. 1982. p. 317-361
13. Bartsch P, Saltin B, Dvorak J. Consensus statement on playing football at different altitude. Scand J Med Sports 2008;18 (suppl.I):96-9.
14. Cossio-Bolaños MA. Crescimento físico e desempenho motor em crianças de 6-12 anos de condição socioeconômica media da área urbana de Arequipa (Perú). Dissertação de mestrado. Unicamp/FEF. Campinas, 2004.
15. The World FactBook (CIA): The work of a nation. The centre of intelligence. Available from:<https://www.cia.gov/library/publications/theworldfactbook/fields/2075.html?countryName= Perú&countryCode=pe&regionCode=sa&# > [2011 jun 14].
16. Marfel-Jones M, Olds TO, Steward A. Carter JEL. International Standards for Anthropometric Assessment. Published by the International Society for the Advancement of Kinanthropometry. Pochefstroom, South Africa. 2006.
17. Ross WD, Wilson NC. A stratagem for proportional growth assessment. Acta Paediatr Belg 1974: 28 (Suppl.):169-82.
18. Berral De la Rosa F, Rodriguez-Anez CR. O estudo das características físicas do homem por meio da proporcionalidade. Rev Bras Cineantropom Desempenho Hum 2002; 4 (1):53-66.
19. Guedes DP, Guedes JR. Somatotipo de crianças e adolescentes do Município de Londrina-Parana-Brasil. Rev Bras Cineantropom Desempenho Hum 1999; 1 (1):7-17.
20. Madureira AS, Sobral F. Estudo comparativo de valores antropometricos entre escolares brasileiros e portugueses. Rev Bras Cineantropom Desempenho Hum 1999;1 (1):53-9.
21. Pucciarelli H, Carnese F, Pinotti L, Guimarey L, Goicoechea A. Sexual dimorphism in schoolchildren of the Villa IAPI Neighborhood (Quilmes, Buenos Aires, Argentina). Am J Phys Anthropol 1993;92:165-72
22. Tanner JM. Growth at adolescence. Oxford: Blackwell 1962.
23. WHO Multicentre Growth Reference Study Group. Assessment of differences in linear growth among populations in the WHO Multicentre Growth Reference Study. Acta Paediatr Suppl 2006;450:56-65.
24. Chia DJ, Boston BA. Childhood obesity and the metabolic syndrome. Adv Pediatrics 2006;53:23-53
25. Malina RM, Bouchard C. Growth maturation and physical activity. Champaign, Human Kinetics 1991.
26. Ross WD, Ward R. Human Proportionality and Sexual Dimorphism. Kines 303-Kinanthropometry. Available from: http://www.sfu.ca/~ward/HumProp.pdf> [2004 Jun 03].
27. Stini WA. Sexual dimorphism and nutrient reserves. In: Hall RL, editor. Sexual Dimorphism in Homo sapiens. New York: Praeger 1982; p. 391-419
28. Eveleth PB, Micozzi MS. Antropometría en el niño y enfermedades crónicas en el adulto. In: Cusminsky M, Moreno E, editors. Crecimiento y desarrollo. OPS, Washington 1988; p. 20-219.

29. Rupert JL, Hochachka PW. Genetic approaches to understanding human adaptation to altitude in the Andes. J Exp Biol 2001;204:3151-60.
30. Greksa LP. Developmental responses to high altitude hypoxia in Bolivian children of European ancestry: A test of the developmental adaptation hypothesis. Am J Hum Biol 1990;2:603-12.

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