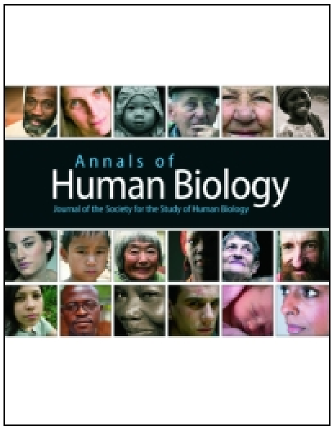

Annals of Human Biology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/iahb20

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Alicia B. Orden[a,b] & María C. Apezteguía[b]

[a] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and

[b] Instituto de Desarrollo e Investigaciones Pediátricas 'Prof. Dr. Fernando E. Viteri' (IDIP - MS/CIC, PBA), Hospital de Niños Sor M. Ludovica, Argentina

Published online: 20 Jul 2015.

Annals of Human Biology
Journal of the Society for the Study of Human Biology

http://informahealthcare.com/ahb
ISSN: 0301-4460 (print), 1464-5033 (electronic)

Ann Hum Biol, Early Online: 1–9
 DOI: 10.3109/03014460.2014.970576

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RESEARCH PAPER

Weight and height centiles of Argentinian children and adolescents: a comparison with WHO and national growth references

Alicia B. Orden[1,2] and María C. Apezteguía[2]

[1]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and [2]Instituto de Desarrollo e Investigaciones Pediátricas 'Prof. Dr. Fernando E. Viteri' (IDIP - MS/CIC, PBA), Hospital de Niños Sor M. Ludovica, Argentina

Abstract

Background: Studies in several countries comparing the performance of WHO references and their own national growth standards reported differences that could affect screening and growth monitoring.
Aim: To estimate weight and height centiles on a sample of Argentinian children and adolescents and compare selected centiles with WHO and national growth references.
Subjects and methods: A cross-sectional school survey was conducted on 6239 boys and girls aged 5–18. Data were collected between 2005–2009 in Santa Rosa, Argentina. Smoothed weight and height centiles were estimated by the LMS method and compared with WHO 2007 and Argentinian (ARG) growth references.
Results: Weight centiles were higher than those of WHO and ARG. Height centiles were above the ARG and below the WHO ones. The greatest differences with ARG were seen before puberty and then declined up to age 18. In contrast, differences with WHO increased from puberty onwards.
Conclusion: Compared with the ARG reference, linear growth of these schoolchildren shows a secular acceleration without substantial improvements in the adult height. In relation to WHO, the results suggest that around the adolescent growth spurt differences in linear growth between populations became larger, limiting the clinical usefulness of international growth references in adolescents.

Keywords

Growth references, schoolchildren, LMS method, Argentina

History

Received 15 May 2014
Revised 18 September 2014
Accepted 25 September 2014
Published online 28 October 2014

Introduction

In 2006, the WHO Multicentre Growth Reference Study (MGRS) published a normative tool for growth assessment in children aged 0–5 years, which would require control of the environmental conditions under which optimal child growth was expected (WHO, 2006). However, the feasibility of developing a single growth standard in schoolchildren and adolescents is limited since it would not be possible to control the dynamics of the environment (Butte et al., 2007; de Onis et al., 2007; Wang et al., 2006). In 2007, WHO published growth references for boys and girls aged 5–19 years, joining the 1977 NCHS databases (Hamill et al., 1977) with the new standards for young children (de Onis et al., 2007). To what extent is this WHO reference suitable for assessing children and adolescents from other populations outside the US? To answer this question it is necessary to compare different populations to the WHO growth reference. Examples of such studies have been conducted in Poland (Kulaga et al., 2010), Germany (Rosario et al., 2011), Spain (Sánchez González et al., 2011), Seychelles (Bovet et al., 2011), China (So et al., 2011; Zong & Li, 2013), Pakistan (Mushtaq et al., 2012), Brazil (Silva et al., 2010) and Chile (Atalah et al., 2012), among others.

If available, national growth standards may be more appropriate to assess growth deviations and abnormal growth. If they are outdated, they may serve as the baselines of any growth surveillance. The Argentinian Society of Paediatrics and the Ministry of Health agreed the use of national growth charts for height and weight from birth to 19 years of age, published in 1987 (Lejarraga & Orfila, 1987; SAP, 2001). The Argentinian growth charts were constructed with longitudinal (0–3 years) and cross-sectional data (4–12 years), which were collected between 1960–1970 in the cities of La Plata and Córdoba (Cusminsky et al., 1974; Funes Lastra et al., 1975). The most recent and representative sample was taken in 1985 and comprised 15 200 students aged between 12–19 from throughout the country (Lejarraga et al., 1986; Lejarraga & Orfila, 1987). Percentiles were recently adjusted by the LMS method, including data from the new WHO (2006) reference for children under 2 years old (Lejarraga et al., 2009).

In 2007, the National Health Ministry recommended using WHO (2006) standards in children younger than 5 years. In older children, there is no consensus about which is the

Correspondence: Alicia B. Orden, Instituto de Desarrollo e Investigaciones Pediátricas (IDIP- MS/CIC, PBA), Hospital de Niños Sor M. Ludovica. Calle 63 N°1069 (1900) La Plata, Argentina. Tel/Fax: #54 221.4535901 int. 1767. E-mail: aborden@conicet.gov.ar

most suitable reference, although in some provinces like Buenos Aires it has been recommended that WHO growth charts are used. This study aims to estimate height and weight centiles in a population of children and adolescents of 5–18 years of age and to compare these centiles with those of the Argentinian and WHO references to determine the pattern of similarities and differences with both instruments. The comparisons here are aimed at contributing information regarding the more general question as to the usefulness of either national or international references for the assessment of growth in children and adolescents from developing countries.

Methods

Socioenvironmental and demographic characteristics

La Pampa is located in an area where production systems are developed in natural environments. In the mid-1990s the province was integrated into the Patagonian region (Southern Argentina). This region is characterized by a low population density resulting from its relatively late settlement along with the displacement of the indigenous population there. Subsequently, the economic and social development of the region has been greatly influenced by settlement policies, such as the movement of army contingents into the region, the implementation of preferential production programmes and higher per capita public investment for social and economic infrastructure, when compared with other regions within the country (Cao & Vaca, 2006). Its population is the result of two main waves of immigration: the first by the inhabitants of neighbouring provinces at the end of the 19th century; the second by the Spanish, Italian, German, French, Jews and Arabs from Europe and the Middle East at the beginning of the 20th century—the ''golden era'' of agricultural colonization. These migration flows occurred between the late 19th and early 20th century and constituted a large proportion of the Argentine genetic and demographic profile. These migrants did not remain isolated, but mixed among themselves and with the local population of ''*Creole*'' (first settlers and native Spanish) to give rise to the present population (except those living in the northwest frontier, with a strong Native American component). In the province of La Pampa, the military campaign of 1880 reduced most of the Amerindian population, so it hardly contributed to the founding population. Unlike other provinces, which in the past 3 decades have received a large migration from neighbouring countries (mostly from Bolivia and Paraguay), migrants to La Pampa were native Argentinians, who came from small towns, rural areas and neighbouring provinces, due to the economic crisis in the 1990s (Tourn, 1996).

Santa Rosa is the capital city and the main urban centre of La Pampa, accounting for 30% of inhabitants of the province. According to the provincial statistical records, by the end of the study the population had ∼111 700 inhabitants (Anuario Estadístico de La Pampa, 2009). In contrast to the province—which is economically organized around primary production—the economy of the capital city is concentrated on the service sector, accounting for 60% of the net regional product. In the last few decades, population growth averaged 24% and city expansion occurred along with a concomitant increase in public services and equipment, covering a large portion of the population's needs. From a socio-demographic and epidemiological point of view the population is ageing, showing an epidemiological profile defined by a predominance of non-communicable diseases as the major causes of morbidity and mortality (MS/OPS, 2009).

Study design, data collection and data analysis

An observational cross-sectional study was carried out in public and private schools from Santa Rosa, between September 2005 and November 2009. Informed consent was requested from the parents or legal guardians, who were previously informed about the objectives and methods of the study. Research protocols were approved by the Ministry of Culture and Education and carried out following the recommendations of the Ethics Committee of the Instituto de Desarrollo e Investigaciones Pediátricas (IDIP-MS/CIC, PBA).

It was performed as sampling by areas, a sub-type of cluster sampling. The city was divided into neighbourhoods and all the schools were mapped. After that, we randomly selected one school in each of the neighbourhoods. In each school selected, all classes were included and all the children were invited to participate. Since Santa Rosa has only three private schools, we randomly chose one of them. At the schools, the participation rate was >95%. Those children who were absent on the day of data collection, those whose parents refused for their children to participate and those children with chronic pathologies were excluded. Besides this participation rate there is the possibility of a selection bias in the late adolescence group. We cannot accurately measure this bias, but there are reasons why we are confident with the results. Secondary education in Argentina is mandatory and, in spite of school dropout, statistical data published in 2010 by the Ministry of Education of La Pampa indicated the mean rate of schooling was 92.3%, with 82.3% for the 15–18 age-group. The subjects finally sampled (3098 boys and 3141 girls) represented ∼20% of this age range within the overall population: ∼18 000 students.

The grouping by age was defined as exemplified by children within their *n*th year: the ages within the *n*-year group extended from 0 years to 99 years (from 5.0–5.99 to 18.0–18.99). Anthropometric measurements of each child were taken at the school by a single observer (ABO) following standardized procedures (Cameron, 2004). Weight was measured to the nearest 0.1 kg with a digital scale (Tanita BF-350, Tanita Corp., Tokyo, Japan) and height was measured to the nearest 0.1 cm with a mobile stadiometer (SECA S-213, Seca, Hamburg, Germany). The reliability measurements fell within acceptable values.

Growth references were generated by the LMS method (Cole & Green, 1992). The method has proven to be a powerful tool for deriving and presenting reference charts. It assumes that data can often be normalized by means of a power transformation, to stretch one tail of the distribution and shrink the other, thereby removing any skewness. The optimal power of a Box-Cox transformation, which obtains approximate normality, is calculated for each of a series of age groups and the trend is summarized by a smooth curve

(L). Trends in the mean (M) and coefficient of variation (S) are similarly smoothed. The resulting curves (L, M and S) contain the information to draw any centile curve and to convert measurements into exact standardized scores.

The first step of data processing was to perform scatter and box plots to remove outliers. The resulting distributions included the mean $\pm$4 SD. After that, weight centiles were estimated on a sample of 3067 boys and 3117 girls. Height centiles were calculated on 3095 boys and 3141 girls. The LMS Pro software used for data management was obtained from the Institute of Child Health (London, UK). Descriptive statistics computed using SPSS v18. LmsChartMaker Light was used to develop the growth curves (Pan & Cole, 2010). The centiles were compared to the WHO 2007 (de Onis et al., 2007) and Argentinian (ARG) growth references (Lejarraga et al., 2009). In this study, BMI is not reported since the ARG lacks BMI centiles. In all cases, comparisons of weight with WHO references were restricted to 5–10 years old. The 3rd, 50th and 97th centiles were plotted along with the corresponding values of WHO and ARG references.

The LMS programme estimates λ, μ and σ values for each age t, with L(t), M(t) and S(t). It also estimates the standard error se(L(t)), se(M(t)), se(S(t)) and the centiles for each age as:

$$C_\alpha(t) = M(t)\cdot[(1 + L(t)\cdot S(t)z_\alpha)1]^{1/L(t)} \text{ or}$$
$$C_\alpha = M\cdot(1 + L\cdot S\cdot z_\alpha)^{1/L} = g(L; M; S)$$

To compare our centiles with those of ARG and WHO, we used the statistic:

$$T = (C_\alpha - ARG_\alpha)/se_{(C\alpha)}$$

The standard errors ($se_{(C\alpha)}$) were calculated approximating the functions which determine the centiles using the first degree Taylor polynomials. Then, se of each centile is expressed by:

$$se_{(C\alpha)} = \sqrt{(a\cdot se(L))^2 + (b * se(M))^2 + (c * se(S))^2}$$

where a, b and c represent the partial derivatives of the function g related to L, M and S:

$$a = \partial g/\partial L = M/L\cdot(1 + L\cdot S\cdot z_\alpha)^{1/L}\cdot[S\cdot z_\alpha/(1 + L\cdot S\cdot z_\alpha) - \ln(1 + L\cdot S\cdot z_\alpha)/L]$$
$$b = \partial g/\partial M = (1 + L\cdot S\cdot z_\alpha)^{1/L}$$
$$c = \partial g/\partial S = M\cdot(1 + L\cdot S\cdot z_\alpha)^{1/L-1}\cdot z_\alpha$$

The significance level was set at $\alpha = 0.05$.

Results

The whole sample comprised 6239 children and adolescents, 49.7% boys (mean age $= 11.7 \pm 3.5$ years) and 50.3% girls (mean age $= 12.1 \pm 3.5$ years). Boys were significantly heavier than girls, except from 7–12 years of age. They were also taller between 5–8 years old and from 13 onwards. At 18 years old, differences between sexes averaged 11.7 kg and 12.7 cm.

The extent of smoothing required was expressed in terms of smoothing parameters or equivalent degrees of freedom (edf), which were selected taking into account the minimal penalized deviance, keeping the order M > S > L.

Weight

The weight edf parameters were L03M06S04 and L03M05S04 in boys and girls, respectively. Smoothed L values for weight varied between -1.74 and -0.29 in boys and from -1.05 and -0.64 in girls (Table 1). Overall, body weight in schoolchildren of Santa Rosa (SR) showed relative similarity to WHO and ARG on the 3rd and 50th centiles, but significant differences on the 97th centile ARG and WHO (SR > AGR > WHO) (Figure 1).

Santa Rosa schoolchildren were heavier than their national sex-age-peers (Figure 2). These differences were related to age, being greater between 11–12 years old in boys and 10–11 years old in girls. Differences in weight also increased from 3rd to 97th centiles. Thus, mean differences between those centiles reached 2.7 (3rd) and 12.6 kg (97th) in boys and 0.8 (3rd) and 8.4 kg (97th) in girls. At 18 years, boys weighed 67.2 kg (50th), 2.4 kg heavier than their national peers. Median weight in girls aged 18 was 55.0 kg, 1.6 kg higher than the ARG reference. Analogous results were found in relation to WHO, with greater differences at the 97th centile compared to the 3rd. At 10 years old, Santa Rosa boys and girls were, respectively, 2.6 kg and 1.9 kg heavier and than their US counterparts.

Height

In height the edf parameters were L01M06S04 in both sexes. Table 2 presents the LMS values and percentiles of height, respectively. Smoothed L values were 0.96 in boys and 0.54 in girls. The overall height was intermediate between both growth references. A ''plateau'' or growth levelling off, starting at ~14 years of age in boys and 12 years of age in girls, placed these children below the WHO curve, bringing them closer to the ARG reference (WHO > SR > ARG, Figure 3).

Calculated height centiles in boys were higher than those of the ARG reference at all ages (Figure 4). In boys such differences were greater between 11–15 years old, reaching ~5 cm at the age of 13 years old. In girls the greatest differences were seen between 9–12 years old, reaching 3.6 cm at 11 years old. At later ages they became progressively close to 0. In contrast to weight, the pattern of differences were similar across the centiles. On average, boys and girls aged 18 measured 174.3 cm and 161.1 cm, respectively. Compared to their national matched peers they were 1.6 cm and 0.4 cm taller. Relative to WHO, differences in boys increased after 11 years of age, reaching -1.8 cm at 18 years old. Differences between centiles in girls were mostly negative and constant up to 11 years. At 18 years old they reached -1.9 cm. Differences were similar across the centiles, ranging from $-0.6 \sim 0.2$ cm in boys, and $-0.7 \sim -1.1$ cm in girls.

Discussion

After the new WHO Child Growth Standard, growth assessment necessarily became a subject of debate, particularly because of the variability in growth patterns across

Table 1. Smoothed weight centiles for school-aged children and adolescents from Santa Rosa (Argentina).

				Centiles						
Sex	Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th
Boys	5	−1.7426	0.1366	15.3	16.3	17.6	19.1	21.1	23.8	27.7
	6	−1.6088	0.1512	16.9	18.1	19.7	21.6	24.1	27.5	32.7
	7	−1.4730	0.1653	18.4	19.9	21.7	24.1	27.2	31.4	37.9
	8	−1.3324	0.1781	20.1	21.9	24.1	26.9	30.6	35.8	43.6
	9	−1.1848	0.1893	22.0	24.1	26.8	30.1	34.5	40.6	49.8
	10	−1.0299	0.1985	24.2	26.7	29.8	33.7	38.9	45.9	56.2
	11	−0.8704	0.2052	26.6	29.5	33.2	37.7	43.6	51.6	62.7
	12	−0.7153	0.2078	29.3	32.8	37.0	42.2	48.8	57.5	69.1
	13	−0.5801	0.2044	32.7	36.7	41.4	47.2	54.4	63.5	75.3
	14	−0.4802	0.1954	36.7	41.1	46.3	52.5	60.1	69.4	81.0
	15	−0.4147	0.1824	40.9	45.5	51.0	57.4	65.0	74.2	85.2
	16	−0.3685	0.1673	44.8	49.5	55.0	61.4	68.8	77.5	87.7
	17	−0.3276	0.1520	48.3	53.0	58.4	64.5	71.5	79.6	88.9
	18	−0.2865	0.1377	51.5	56.2	61.4	67.2	73.7	81.1	89.5
Girls	5	−1.0522	0.1548	14.1	15.3	16.7	18.4	20.5	23.2	26.8
	6	−0.9535	0.1667	15.7	17.1	18.8	20.9	23.5	26.9	31.3
	7	−0.8567	0.1782	17.3	19.0	21.1	23.6	26.8	30.8	36.2
	8	−0.7695	0.1882	19.1	21.1	23.6	26.6	30.3	35.1	41.5
	9	−0.7036	0.1954	21.2	23.6	26.4	30.0	34.3	40.0	47.3
	10	−0.6611	0.1988	23.7	26.4	29.7	33.8	38.8	45.2	53.5
	11	−0.6394	0.1973	26.7	29.7	33.4	37.9	43.5	50.6	59.8
	12	−0.6390	0.1906	30.0	33.3	37.3	42.2	48.2	55.7	65.3
	13	−0.6571	0.1790	33.4	36.9	41.1	46.1	52.2	59.8	69.3
	14	−0.6866	0.1654	36.5	40.1	44.3	49.2	55.2	62.5	71.7
	15	−0.7201	0.1533	39.1	42.6	46.7	51.5	57.3	64.3	72.9
	16	−0.7538	0.1438	40.9	44.4	48.4	53.1	58.7	65.3	73.4
	17	−0.7922	0.1365	42.3	45.7	49.6	54.1	59.5	65.9	73.6
	18	−0.8352	0.1295	43.5	46.8	50.6	55.0	60.1	66.3	73.6

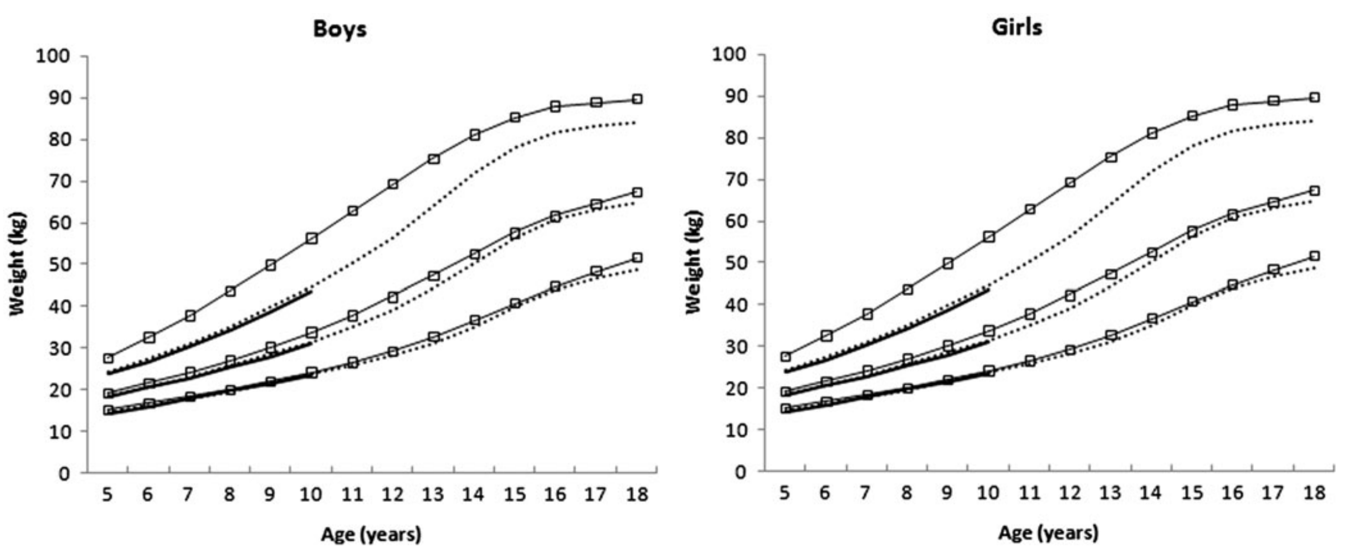

Figure 1. Growth curves illustrate the 3rd, 50th and 97th centiles for weight in boys and girls from Santa Rosa (SR: black line and squares), WHO (black line) and ARG (dotted line) references.

populations and the lack of local standards in many countries (Butte et al., 2007). Argentina is one of the few Latin American countries that has its own growth charts from birth to 19 years of age. The Argentinian growth reference was built during two great periods: between 1960–1970 for children younger than 12 and during 1985 for adolescents from 12–19 years of age. In 2009, this reference was smoothed according to LMS method, incorporating data from infants aged 0–2 from the new child WHO standard (Lejarraga et al., 2009).

Beyond the methodological improvement of the Argentinian reference, original data are nearly 30 years old, raising the question of their current validity. Moreover, as a result of ethnic, social, cultural and economic differences, a positive secular trend may be occurring in some regions of the country. In fact, a recent study in pre-adolescents of Santa Rosa aged 6–12 years found that a low rate of change in stature along with a significant increase in body weight had occurred between 1990–2007 (Orden et al., 2013). The authors also observed the biggest changes at the upper centiles of weight and BMI distributions, with relatively little or no changes below the 50th centiles. In comparative terms, the current weight data could not be contrasted with WHO

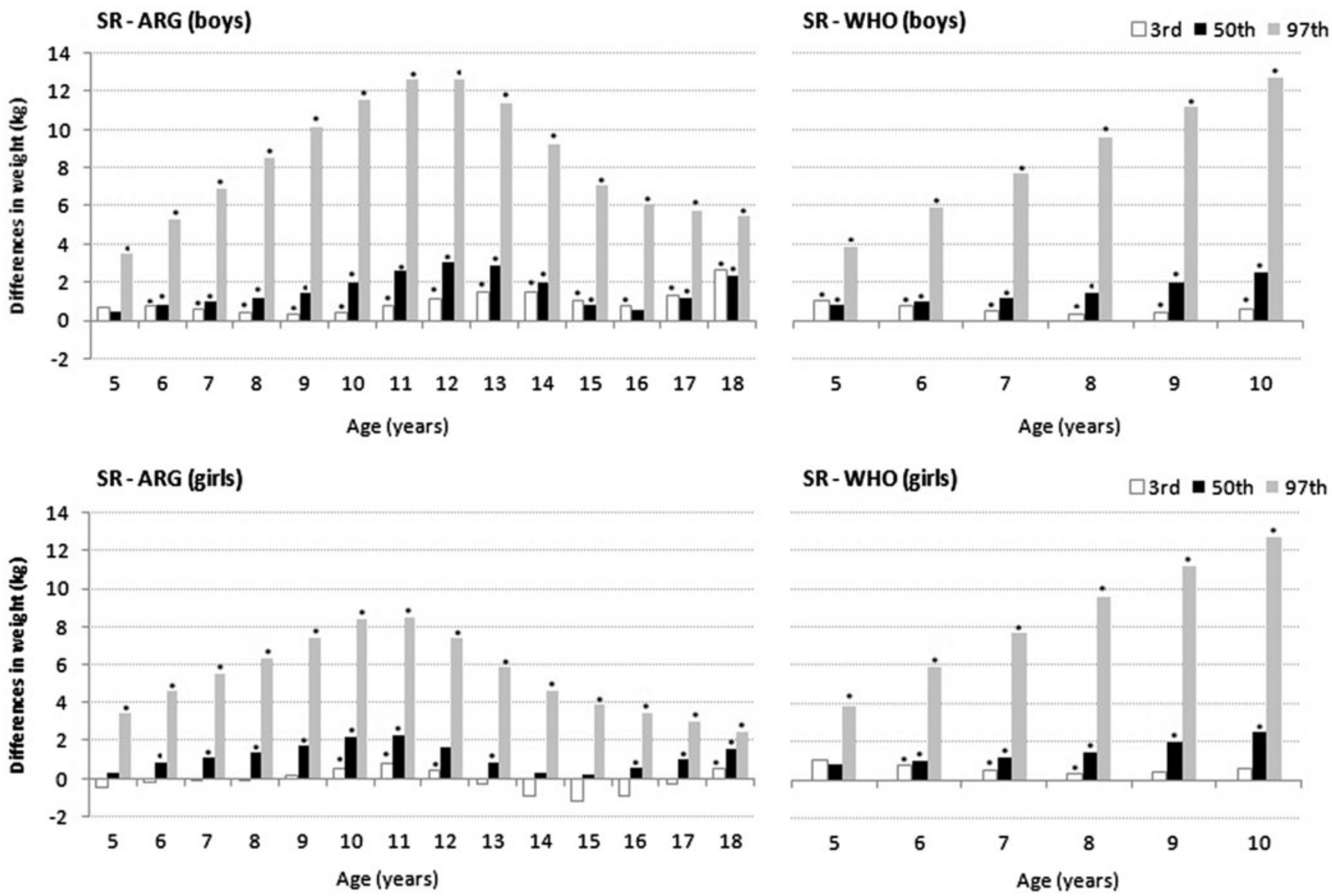

Figure 2. Differences in weight centiles between the sample (SR), ARG and WHO references. Positive values indicate higher weights in the sample than the references and vice versa. *$p \leq 0.05$.

Table 2. Smoothed height centiles for school-aged children and adolescents from Santa Rosa (Argentina).

				Centiles						
Sex	Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th
Boys	5	0.9584	0.0409	101.3	104.3	107.3	110.3	113.3	116.3	119.3
	6	0.9584	0.0417	106.4	109.6	112.8	116.1	119.3	122.5	125.8
	7	0.9584	0.0426	111.4	114.8	118.3	121.7	125.2	128.6	132.1
	8	0.9584	0.0434	116.2	119.9	123.5	127.2	130.9	134.6	138.3
	9	0.9584	0.0445	120.7	124.6	128.6	132.5	136.4	140.4	144.3
	10	0.9584	0.0460	125.2	129.4	133.7	137.9	142.1	146.4	150.6
	11	0.9584	0.0477	130.0	134.5	139.1	143.7	148.2	152.8	157.4
	12	0.9584	0.0491	135.3	140.2	145.1	150.0	154.9	159.8	164.7
	13	0.9584	0.0493	141.1	146.2	151.4	156.5	161.7	166.8	172.0
	14	0.9584	0.0481	147.1	152.3	157.5	162.7	167.9	173.1	178.3
	15	0.9584	0.0455	152.5	157.6	162.7	167.8	172.9	178.0	183.1
	16	0.9584	0.0426	156.7	161.6	166.4	171.3	176.1	181.0	185.9
	17	0.9584	0.0397	159.5	164.1	168.7	173.3	177.9	182.5	187.1
	18	0.9584	0.0371	161.4	165.7	170.0	174.3	178.6	183.0	187.3
Girls	5	0.5444	0.0447	99.5	102.7	105.9	109.1	112.4	115.7	119.0
	6	0.5444	0.0450	104.5	107.8	111.2	114.6	118.1	121.6	125.1
	7	0.5444	0.0453	109.6	113.1	116.6	120.2	123.9	127.6	131.4
	8	0.5444	0.0457	114.7	118.4	122.1	125.9	129.8	133.7	137.7
	9	0.5444	0.0459	120.0	123.9	127.9	131.9	136.0	140.1	144.2
	10	0.5444	0.0455	125.7	129.7	133.8	138.0	142.2	146.5	150.8
	11	0.5444	0.0443	131.7	135.8	139.9	144.2	148.5	152.8	157.2
	12	0.5444	0.0424	137.6	141.7	145.8	150.0	154.3	158.6	163.0
	13	0.5444	0.0401	142.5	146.5	150.6	154.7	158.9	163.1	167.3
	14	0.5444	0.0381	145.9	149.8	153.7	157.7	161.7	165.8	169.9
	15	0.5444	0.0369	147.9	151.7	155.5	159.4	163.4	167.4	171.4
	16	0.5444	0.0361	149.0	152.8	156.6	160.4	164.3	168.2	172.2
	17	0.5444	0.0355	149.6	153.3	157.1	160.9	164.7	168.5	172.5
	18	0.5444	0.0349	150.0	153.7	157.4	161.1	164.9	168.7	172.6

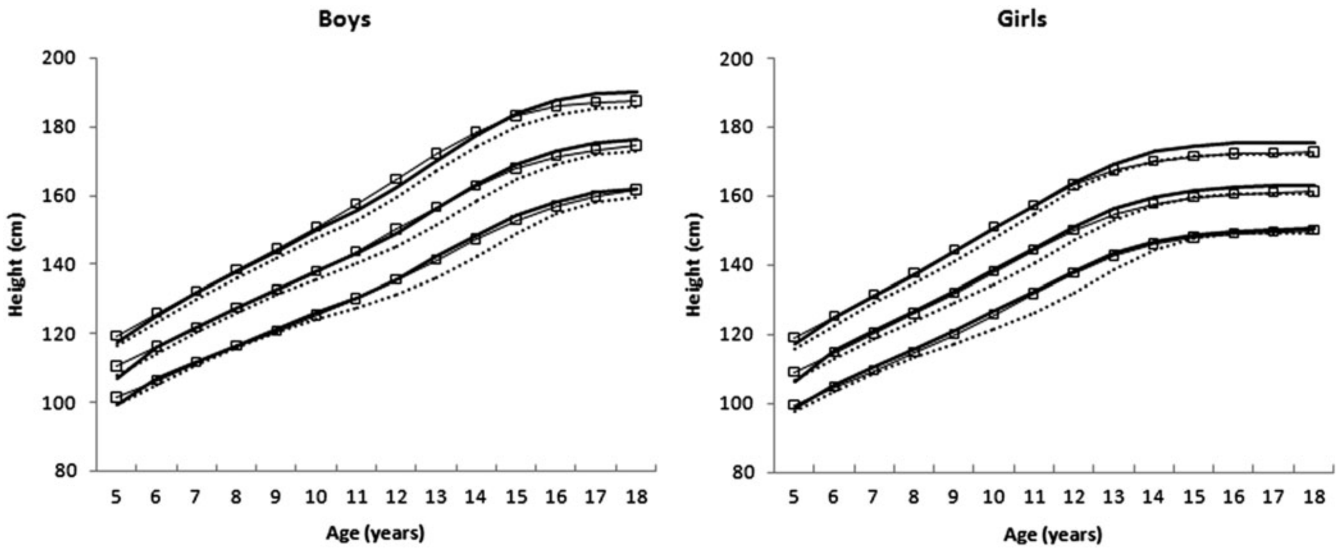

Figure 3. Growth curves illustrate the 3rd, 50th and 97th centiles for height in boys and girls from Santa Rosa (SR: black line and squares), WHO (black line) and ARG (dotted line) references.

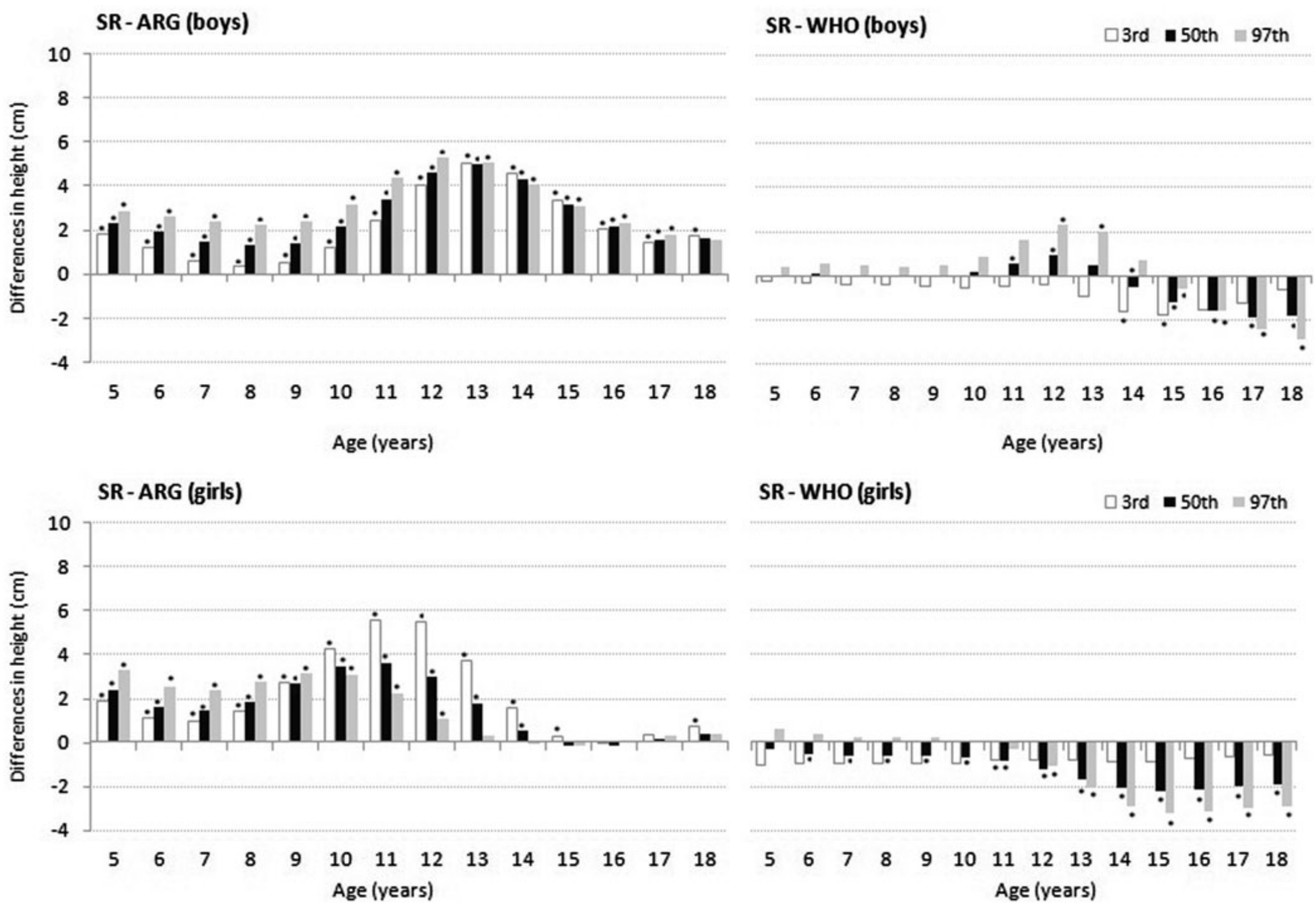

Figure 4. Differences in height centiles between the sample (SR), ARG and WHO references. Positive values indicate higher heights in the sample than the references and vice versa. $*p \leq 0.05$.

beyond 10 years of age. On the other hand, the ARG reference lacks BMI centiles, limiting our analysis. Nevertheless, when the weight centiles of the sample were compared to both data references, a higher body mass was revealed in these schoolchildren, whose biased distribution was self-evident at the 97th centile, corroborating both previous results as well as those reported in other populations (Kulaga et al., 2011; López-Siguero et al., 2008; Roelants et al., 2009). The most significant changes at the upper centiles have logical consequences because a global trend towards increased body weight in childhood and adolescence is consequently followed by a rise in overweight and obesity (Wang & Lobstein, 2006). These effects—perhaps—denote one of the most currently valuable functions of growth charts for public health, as a screening and monitoring tool to assess body weight disturbances.

Another study on the same population (Orden et al., 2009), surveyed between 2005–2007, evidenced that height of schoolchildren aged 5–14 years, showed a clear dissociation from the national reference and minor differences from CDC. Around puberty, however, the children's height fell short of CDC, especially the girls, whose values approached those of their Argentinian peers. Two years later, many of these young schoolchildren were re-assessed, in order to test if such deviation from CDC and the approach to ARG may be due to some age-cohort effect. Such an effect, however, was ruled out since a divergence from CDC toward the national reference was also observed (Orden, 2011). This relative fall in height has been reported in several studies (Bener & Kamal, 2005; dos Anjos et al., 2003; Haas & Campirano, 2006; Hakeem et al., 2004; Hasan et al., 2001), showing variations in growth between populations.

In terms of distribution, it was found that these Argentinian adolescents still fit generally the Argentinian norms for this age-range. The stature of boys under 17, however, was significantly higher than that of their ARG peers. This does not mean that the national reference is less adequate to assess this population than the international one. In fact, the present results indicate that adolescents are closer to ARG than the pre-adolescents are. It could be explained because of the two different periods of ARG reference construction, so that it would be outdated for pre-pubertal ages, but not for adolescents. Although the results may indicate no substantial changes of the height in the last 25 years, it is possible that these young people reach maturation earlier than those born in the 1980s, when the national reference for adolescents was constructed. To support this assumption requires having maturity indicators. The only maturation milestone we know in this population is the age at menarche, established as 12.84 years (Orden et al., 2011). After applying a Preece-Baines model for population-derived cross-sectional data (Zemel & Johnston, 1994) we found results that were consistent with the age at menarche: age at PHV of 11.8 and 13.7 years in girls and boys, respectively. Unfortunately, we cannot ensure whether these values represent an acceleration of maturational tempo because: (1) the reference for age at menarche (mean age = 12.5 years, median age = 12.69 years) published by Lejarraga et al. (1980) corresponds to a sample of middle socioeconomic status girls of the city of La Plata and not to the ARG reference, in which the age-group 12–18 years was surveyed in 1985; (2) given the ARG reference was constructed by cross-sectional samples, there are no national values for PHV. Thus, the only certain data which support the idea of secular acceleration are the measures of final height. Thus, if the ARG reference is considered as the baseline to detect secular changes, a secular acceleration is consistent with higher statures before puberty, without a significant change of final height. Additionally, data from the army (which for many years was the greatest reservatory of probabilistic samples of 18 years boys) recorded statures of 174 cm in boys born in 1975 and recruited in 1993 (PPAN, 1999). These secular changes towards an earlier growth spurt and growth tempo have been observed in several populations, so that boys and girls are taller at earlier ages (Khadilkar et al., 2009; Kulaga et al., 2010; Sánchez González et al., 2011; So et al., 2011; Zong & Li, 2013), and also in multiethnic societies, where children of migrants appear to be comparably tall and heavy at late puberty, but remain shorter after puberty (Redlefsen et al., 2007).

Advanced growth was also seen in relation to the WHO reference, especially for the boys, whose heights were closer to their American age peers than girls. Similarly, Komlos & Breitfelder (2007) compared growth curves of US (CDC) and Dutch boys and girls, the latter representing the tallest individuals in the current world. They found both curves were more similar before puberty, but thereafter the US median deviated negatively to reach the Dutch 25th centile. As a result of these differences in tempo of growth and maturation, it is noticeable the Dutch measure ~6 cm more than their US age peers. The authors observed that, before the Second World War, the Americans used to be taller than the Dutch, which supports the hypothesis that differences between these populations are due mainly to environment. In this sense, Komlos & Breitfelder (2007: 601) stated

> . . . the use of Dutch height references gives US parents an opportunity to gauge their children's growth relative to a 'world standard' in a similar fashion as the World Health Organization uses reference values from six countries as an ideal standard for the world population . . ..

At the same time, Rosario et al. (2011) indicated the inconvenience of applying a US reference to infants, children and adolescents from Germany, due to the fact they are taller than CDC and WHO growth references.

Seidell et al. (2006) compared children of different countries who had grown and maturated at different rates. The authors analysed data from seven national surveys and measured height growth as a proportion of adult height. Using stature as a proxy of maturation they concluded that there is no single growth pattern for adolescents around the world. The reasons why growth and maturation patterns vary across populations are currently widely debated. Intra-uterine factors, breast-feeding patterns, nutritional status, physical activity, urbanization, as well as the epigenetic interaction between genetic and environmental factors can potentially contribute to health and growth inequalities, but their relative importance is still unclear (van Buuren & van Wouwe, 2008). The question is: do our genes have the same growth potential? Thomis & Towne (2006) stated that, although genetic basis may be essentially the same in different populations, there may be differences in the gene-by-environment interactions and it is reasonable to hypothesize that population differences in growth and maturation may become smaller in the upcoming decades; but at the same time it is also reasonable to hypothesize that the genetic basis of such differences will remain and will become primary sources of inter-population differences in measures of growth and maturation.

It has been argued that, in contrast to early childhood, growth in later childhood and adolescence evidences inter-population differences in growth and maturation so that a single reference fails to adequately express the diversity of human growth (Hermanussen et al., 2012). Beyond the nature of the differences, the international growth charts do not take into account variations in healthy growth among populations, which requires that countries generate their own growth standards (Beunen et al., 2006; Milani et al., 2012). Meanwhile it is legitimate to use common international references under a descriptive-comparative perspective, to understand the variability and plasticity of human growth.

Conclusions

The present centiles of weight and height of schoolchildren from Northern Patagonia are not intended to reflect the growth of all Argentinian children and adolescents, nor are they supposed to be used as a growth standard. They provide, however, a descriptive perspective of the current physical growth of urban Argentinian children and adolescents in relation to national and international growth references, which may be used as a comparative parameter for investigations in different regions of the country. If the ARG reference is taken as the baseline, the pattern of differences in body weight show clear evidence of the positive trend of overweight in this population. Thus, in a general sense, these schoolchildren are now fatter than their national age peers surveyed before 1985. In contrast the linear growth of these Argentinian schoolchildren has not shown substantial improvements in the last two decades, considering that the national reference for this age-group was built almost 30 years ago. However, it is possible that changes in growth rates and maturation are happening since pre-pubertal boys and girls are taller than their national age peers. This effect may also explain why these schoolchildren, especially boys, are not so different from international references up to late adolescence. Growth variations between populations become larger during adolescence, resulting in differences in adult size, so that universal references should be used only with descriptive-comparative purposes for the anthropometric assessment of adolescents in developing countries like Argentina. At the same time, the national reference would seem more appropriate for clinical use in the country.

Acknowledgements

The authors are grateful to the authorities of the Ministry of Culture and Education of La Pampa, school authorities, teachers, parents and adolescents for their unselfish participation and also wish to thank Constanza Fernández for invaluable collaboration during the survey and Sebastián Consoli for editing the final version of the manuscript.

Declaration of interest

The authors report no conflicts of interest. Contract grant sponsor: ANPCYT PICT 14095 and CONICET PIP 114-200801-00390.

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