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: 1–8
 DOI: 10.3109/03014460.2014.968207

informa
healthcare

RESEARCH PAPER

Weight and height percentiles calculated by the LMS method in Argentinean schoolchildren. A comparative references study

Evelia E. Oyhenart[1,2], Delia B. Lomaglio[3], Silvia L. V. Dahinten[4], Ignacio F. Bejarano[5], Ángel Herráez[6], María F. Cesani[2], María F. Torres[2,7], María A. Luis[1], Fabián A. Quintero[1,2], Emma L. Alfaro[5], Alicia B. Orden[8], María L. Bergel Sanchis[2], Marisa González-Montero de Espinosa[6], Mariela Garraza[2], María E. Luna[2], Luis M. Forte[1], María S. Mesa[6], Susana Moreno Romero[6], Noemí López-Ejeda[6], José E. Dipierri[5], and María D. Marrodán[6]

[1]Facultad de Ciencias Naturales y Museo, [2]Instituto de Genética Veterinaria, Facultad de Ciencias Veterinarias, Universidad Nacional de La Plata, La Plata, Buenos Aires, Argentina, [3]Centro de Estudios de Antropología Biológica. Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Catamarca, San Fernando del Valle de Catamarca, Catamarca, Argentina, [4]Centro Nacional Patagónico, Puerto Madryn, Chubut, Argentina, [5]Instituto de Biología de la Altura, Universidad Nacional de Jujuy, San Salvador de Jujuy, Jujuy, Argentina, [6]Grupo de Investigación en Epidemiología Nutricional, Departamento de Zoología y Antropología Física, Facultad de Ciencias Biológicas, Universidad Complutense de Madrid, Madrid, España, [7]Facultad de Filosofía y Letras, Universidad de Buenos Aires, Ciudad Autónoma de Buenos Aires, Argentina, and [8]Instituto de Desarrollo e Investigaciones Pediátricas, Hospital de Niños Sor María Ludovica, La Plata, Buenos Aires, Argentina

Abstract

Background: The Argentinean population is characterized by ethnic, cultural and socio-economic diversity.
Aim: To calculate the percentiles of weight-for-age (W/A) and height-for-age (H/A) of schoolchildren from Argentina employing the LMS method; and to compare the obtained percentiles with those of the international and national references.
Subjects and methods: Anthropometric data of 18 698 students (8672 girls and 10 026 boys) of 3–13 years old were collected (2003–2008) from Buenos Aires, Catamarca, Chubut, Jujuy, La Pampa and Mendoza. Percentiles of W/A and H/A were obtained with the LMS method. Statistical and graphical comparisons were established with the WHO (international reference) and with that published by the Argentinean Paediatric Society (national reference).
Results: Differences in W/A and H/A, regarding the references, were negative and greater at the highest percentiles and in most of the age groups. On average, the differences were greater for boys than girls and for national than international references.
Conclusion: The distribution of weight and height of schoolchildren, coming from most regions of the country, differs from those of national and international references. It should be advisable to establish a new national reference based on internationally recognized methodological criteria that adequately reflect the biological and cultural diversity of the Argentinean populations.

Keywords

Argentinean reference, children growth, WHO reference

History

Received 13 June 2014
Revised 15 August 2014
Accepted 8 September 2014
Published online 30 October 2014

Introduction

Human populations differ in growth patterns because of ontogenetic plasticity. Growth patterns result from the interaction of multiple environmental contingencies that modulate the expression of the genetic potential. These environmental factors are characterized by temporal and spatial variations (Ulijaszek et al., 2000). The evaluation of growth and development patterns resulting from this genetic-environmental interaction is one of the most appropriate indicators to estimate the nutritional and health status of populations and, indirectly, their quality-of-life.

In Argentina, auxological assessments were carried out in populations from different geographical and socio-cultural environments, showing heterogeneity in growth patterns. The diversity found was attributed mainly to the effect of biological (age and sex) and environmental (geo-climatic, economic, social and cultural features) factors that characterize a vast country (Alfaro et al., 2004; Bejarano et al., 2001; Dahinten et al., 2011; Dipierri et al., 1998; Orden et al., 2009; Oyhenart et al., 2008, 2013). In this sense, in a previous collaborative multi-centre study conducted between 2003–2005, body weight and height were measured in a sample of 15 011 children, aged 3–18 years, of 102 schools from different provinces of Argentina (Oyhenart et al., 2008). The results of this study, in which the National Centre for Health Statistics (NCHS) reference was employed, indicated differences between geographical areas: while under-nutrition decreased from north to south, overweight and obesity showed an opposite direction.

On the other hand, several studies revealed that the anthropometric assessment results showed considerable

Correspondence: Dr Evelia Edith Oyhenart, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata (UNLP), Calle 64 N° 3, La Plata, Buenos Aires, Argentina, CP 1900. Tel: 00 54 221 4246305. E-mail: oyhenart@fcnym.unlp.edu.ar

differences depending on the standard or reference used (Alfaro et al., 2008; Bergel et al., 2014; Bonthuis et al., 2012; De Onis & Garza, 1997; Hermanussen et al., 2010; Oyhenart & Orden, 2005). It has been argued that differences may be due to some problems such as the construction of standards and references (Cole, 1989; Cole & Green, 1992; Hermanussen et al., 2010; Ulijaszek et al., 2000). Originally, the curves were manually drawn and smoothed to fit (Rebato et al., 2002) and they are currently used in Argentina in this way (Lejarraga & Orfila, 1987; Sociedad Argentina de Pediatría, 2001). According to several authors, the use of statistical methods based on mathematical models to fit and smooth out curves indicates kurtosis and skewness of raw anthropometric data. These data allow the accurate representation of their changes and trends in terms of age and have contributed to solve that problem (Cole, 1994; Kuczmarski et al., 2002). One of these non-structural mathematical models is the LMS (the abbreviation refers to smooth curve-L, mean-M and coefficient of variation-S) which assumes that anthropometric data for each age group can be transformed to normal distribution scores and then correctly reconstructed to the original percentiles (Alfaro et al., 2008; Cole, 1990; WHO, 2006). Accordingly, the aim of this study was: (a) to calculate the percentiles of weight-for-age (W/A) and height-for-age (H/A) of schoolchildren from Argentina, employing the LMS method; and (b) to compare the obtained percentiles with those of international and national references.

Methods

Population study

Data were collected between 2003–2008. The sample consisted of 18 698 schoolchildren aged 3–13 years (10 026 boys, 8672 girls), living in six provinces from four regions of the five sanitary regions of Argentina (Oyhenart et al., 2008): (1) Centro: $n = 4753$; province of Buenos Aires (Brandsen and La Plata cities); (2) Noroeste: $n = 5565$; provinces of Catamarca (San Fernando del Valle de Catamarca city) and Jujuy (San Salvador de Jujuy, Susques, Fraile Pintado and Humahuaca cities); (3) Cuyo: $n = 3188$; province of Mendoza (General Alvear city) and Sur: $n = 5192$; provinces of Chubut (Puerto Madryn) and La Pampa (Santa Rosa and Toay cities). These study regions and their demographic, economic, social and environmental characteristics have been previously reported by Oyhenart et al. (2008) and are summarized in Tables 1 and 2.

Anthropometry study

The anthropometric study was carried out following standardized protocols (Weiner & Lourie, 1981). The following variables were recorded: age (A) (years), obtained from identification cards or school records; body weight (W) (Kg), measured on a digital scale (accuracy, 100 g) with the subjects lightly clothed (weight of clothes was subtracted); and height (H) (cm), using a portable vertical anthropometer (accuracy, 1 mm).

Instruments were calibrated at the beginning of each anthropometric session. Dispersion of raw data and outliers were removed using ±4 SD as a cut-off. This criterion

Table 1. Summary of main demographic, economic and social indicators for the regions analysed.

						Gross Domestic Product (GDP)									
							GDP by sector (1)				Households under poverty and indigence (2)			Mortality due to under-nutrition in children under 5 years (from 2000–2004) (1)	
Region	Province (1)	Department (2)	City	Population (inhabitants) (2)	Population Density (inhabitant/km^2) (2)	Total ($) (1)	Primary (%)	Secondary (%)	Tertiary (%)	Children aged 0–14 without health insurance (%) (2)	Poverty (%)	Indigence (%)	Infant mortality rate (1/1000) (1)	2000 (1/10 000)	2004 (1/10 000)
Cuyo	Mendoza	General Alvear	General Alvear	42 338	2.93	8 737 526	14.2	29.7	56.1	64.3	24.8	7.9	13.5	2	1
Noroeste	Jujuy	Dr. Manuel Belgrano	San Salvador de Jujuy	184 920	96.5	1 902 828	9.4	24.7	65.9	52.5	40.8	11.6	17.8	5	3
	Catamarca	Capital	San Fernando del Valle de Catamarca	110 189	161.1	1 117 703	2.8	29.8	67.5	45.6	41.3	13.6	21.8	1	3
Centro	Buenos Aires	Brandsen	Coronel Brandsen	18 424	16.3	70 776 296	4.9	34.9	60.2	49.9	17.3	4.7	13.0	13	16
	Buenos Aires	La Plata	La Plata	541 905	585.2					45.6					
Sur	La Pampa	Capital	Santa Rosa	78 022	30.9	1 893 968	22.1	15.1	62.8	45.7	21.2	6.1	14.6	–	–
	La Pampa	Toay	Toay	6 860	1.4					50.9					
	Chubut	Biedma	Puerto Madryn	45 494	3.5	2 887 597	18.6	23.8	57.7	39.2	14.6	5.9	11.8	1	–

Modified from Oyhenart et al. (2008).
(1) Data refer to provincial political division (Province). (2) Data refer to departmental political division (Department)

Table 2. Summary of main environmental indicators for the regions analysed.

Region	Province (1)	Department (2)	City	Poor housing (%) (2)	Without pipe water inside the house (%) (2)	WC without water discharge or without WC (%) (2)	Dirt floors (%) (2)	Overcrowding (%) (2)
Cuyo	Mendoza	General Alvear	General Alvear	4.6	24.5	23.3	5.2	6.7
Noroeste	Jujuy	Dr. Manuel Belgrano	San Salvador de Jujuy	7.7	17.9	22.4	8.2	12.2
	Catamarca	Capital	San Fernando del Valle de Catamarca	2.3	11.3	15.3	4.2	10.7
Centro	Buenos Aires	Brandsen	Coronel Brandsen	8.0	8.3	17.6	2.4	6.9
		La Plata	La Plata	6.0	18.0	10.6	1.5	4.5
Sur	La Pampa	Capital	Santa Rosa	1.3	4.8	4.8	1.3	5.3
		Toay	Toay	2.1	13.2	12.6	2.1	6.4
	Chubut	Biedma	Puerto Madryn	1.9	6.0	9.2	2.8	8.4

Modified from Oyhenart et al. (2008).
(1) Data refer to provincial political division (Province). (2) Data refer to departmental political division (Department).

eliminated 129 cases from the total (0.60%). Data were grouped by sex and age groups.

To calculate weight and height percentiles, the LMS method was applied to synthesize the changing distribution of these anthropometric measurements during growth as a function of age. The curves L, M and S represent asymmetry (lambda), median (mu) and coefficient of variation (sigma), respectively. The LMS method uses the Box-Cox transformation to adjust the distribution of anthropometric data to a normal distribution by minimizing the effects of asymmetry. The parameters L, M and S were calculated according to the method of maximum penalized likelihood (Cole & Green, 1992). W/A and H/A were estimated from those values applying the following formula (Cole, 1989):

$$P = M[1 + LSZ]^{\frac{1}{L}}$$

where L, M and S are the values calculated for each age and Z is the value corresponding to the percentile sought.

The calculated percentiles were 3, 10, 25, 50, 75, 90 and 97. Data processing was performed using the LMS Chartmaker Pro software (The Institute of Child Health, London, UK) (Pan & Cole, 2011). A Q-test was used to establish the goodness-of-fit according to the recommended procedure. The calculated percentiles for each age and sex were compared with those previously reported by the World Health Organization (De Onis et al., 2007; WHO, 2006) and by Lejarraga et al. (2009) using the following formula:

$$100 \ \log\left(\frac{\text{percentile of reference}}{\text{percentile calculated}}\right)$$

Ethics statement

This study was approved by the Agencia Nacional de Promoción Científica y Tecnológica and the Universidad Nacional de Jujuy, Argentina and by Ministerio de Ciencia y Tecnología del Gobierno de España, Spain, as well as by local authorities and educational and sanitary staff. Research protocols followed the principles outlined in the Helsinki Declaration (WMA, 2001).

None of the schoolchildren showed pathological history. The goals and procedures of the study were explained during meetings held in each school. Informed consent was signed by the children's parents. Children whose parents did not sign the forms were not measured. In addition, the children themselves were consulted and only those who agreed (orally) were included in the study.

Results

Tables 3 and 4 show the values of percentiles 3, 10, 25, 50, 75, 90 and 97 for W/A and H/A, respectively, and L, M and S parameters in boys and girls.

Figures 1 and 2 illustrate the comparison of percentiles 3, 50 and 97 obtained in this study, along with those of international and national references. This comparison indicated that the percentile values calculated for both indices (W/A and H/A) were equal to or greater than those of the references.

According to the Cole (1989) formula, discrepancies between the calculated values and the references have a plus sign (+) when the reference value is greater than the calculated one and minus sign (−) when the opposite occurs. Thereby, the calculated percentiles for W/A and H/A were equal to or greater than those of both references (Tables 5 and 6).

Moreover, W/A percentile differences in both boys and girls were negative in all percentile values and age groups (Table 5). The average differences in P50 for the sample in relation to the international reference were 1.92 kg for boys and 1.51 kg for girls, corresponding to a 3.77%, and 2.96% variation, respectively. On the other hand, in P50, boys and girls were on average 2.25 kg and 1.80 kg heavier than those of the national reference, with a percentage difference of 3.33% and 2.91%, respectively (Table 5).

Percentile difference for H/A was negative and had a larger magnitude at the highest percentiles. Exceptions were observed in girls in P3 at 9–13 years and in P50 and P97 at 13 years (Table 6). On average, these differences were greater in boys than in girls and also greater in national than in international references. In relation to P50 of the national reference, boys were on average 3.69 cm and girls 3.71 cm taller than those of the national reference. This resulted in percentage differences of 1.28% and 1.29% for boys and girls, respectively. For the international reference, differences were

Table 3. Percentiles (P) values and L, M, S parameters of weight-for-age, by sex and age.

Age	*n*	P3	P10	P25	P50	P75	P90	P97	L	M	S
Boys											
3	167	12.87	13.63	14.53	15.73	17.22	18.93	21.12	−1.58	15.73	0.13
4	336	14.40	15.31	16.40	17.87	19.72	21.86	24.66	−1.51	17.87	0.14
5	819	15.96	17.04	18.34	20.11	22.37	25.02	28.55	−1.44	20.11	0.15
6	1080	17.41	18.68	20.21	22.31	25.01	28.22	32.54	−1.36	22.31	0.16
7	928	18.93	20.41	22.21	24.69	27.90	31.75	36.98	−1.27	24.69	0.17
8	1102	20.66	22.40	24.53	27.47	31.30	35.91	42.20	−1.17	27.47	0.18
9	1138	22.53	24.58	27.10	30.59	35.14	40.61	48.04	−1.04	30.59	0.19
10	1040	24.62	27.05	30.03	34.15	39.50	45.89	54.44	−0.90	34.15	0.20
11	1211	27.14	30.02	33.53	38.37	44.58	51.86	61.36	−0.75	38.37	0.21
12	1225	30.20	33.60	37.70	43.28	50.30	58.31	68.41	−0.59	43.28	0.21
13	980	33.61	37.52	42.19	48.41	56.05	64.49	74.73	−0.44	48.41	0.21
Girls											
3	192	12.39	13.22	14.18	15.46	17.02	18.74	20.87	−1.18	15.46	0.13
4	319	13.73	14.71	15.87	17.40	19.29	21.39	24.01	−1.11	17.40	0.14
5	672	15.08	16.23	17.59	19.41	21.66	24.20	27.38	−1.04	19.41	0.15
6	935	16.47	17.82	19.42	21.56	24.24	27.28	31.12	−0.98	21.56	0.16
7	995	17.97	19.53	21.40	23.93	27.11	30.74	35.38	−0.92	23.93	0.17
8	904	19.60	21.42	23.61	26.58	30.34	34.67	40.23	−0.86	26.58	0.19
9	929	21.60	23.73	26.31	29.82	34.26	39.38	45.95	−0.78	29.82	0.20
10	971	24.15	26.67	29.71	33.84	39.04	44.99	52.54	−0.69	33.84	0.20
11	983	27.31	30.28	33.84	38.62	44.57	51.25	59.54	−0.57	38.62	0.20
12	1007	30.67	34.08	38.11	43.45	49.94	57.05	65.59	−0.44	43.45	0.20
13	765	33.64	37.39	41.75	47.42	54.13	61.26	69.55	−0.30	47.42	0.19

Table 4. Percentiles (P) values and L, M, S parameters of height-for-age, by sex and age.

Age	*n*	P3	P10	P25	P50	P75	P90	P97	L	M	S
Boys											
3	167	90.78	93.28	95.86	98.81	101.82	104.61	107.42	0.16	98.81	0.04
4	336	97.00	99.68	102.47	105.66	108.93	111.96	115.02	0.08	105.66	0.05
5	819	102.95	105.83	108.82	112.24	115.76	119.03	122.34	0.02	112.24	0.05
6	1080	108.15	111.19	114.36	117.99	121.74	125.22	128.74	−0.01	117.99	0.05
7	928	112.86	116.07	119.41	123.24	127.19	130.86	134.58	0.00	123.24	0.05
8	1102	117.42	120.82	124.35	128.39	132.56	136.43	140.34	0.04	128.39	0.05
9	1138	121.81	125.42	129.18	133.47	137.88	141.96	146.09	0.12	133.47	0.05
10	1040	126.34	130.23	134.25	138.83	143.53	147.85	152.22	0.25	138.83	0.05
11	1211	131.40	135.61	139.95	144.86	149.86	154.44	159.03	0.46	144.86	0.05
12	1225	136.97	141.53	146.19	151.42	156.68	161.47	166.22	0.74	151.42	0.05
13	980	142.52	147.42	152.36	157.82	163.26	168.14	172.93	1.13	157.82	0.05
Girls											
3	192	89.63	92.21	94.85	97.84	100.86	103.62	106.38	0.53	97.84	0.05
4	319	95.45	98.24	101.10	104.32	107.59	110.56	113.52	0.59	104.32	0.05
5	672	101.06	104.07	107.14	110.60	114.10	117.28	120.45	0.64	110.60	0.05
6	935	106.25	109.47	112.77	116.46	120.19	123.58	126.95	0.70	116.46	0.05
7	995	111.08	114.52	118.04	121.97	125.94	129.53	133.10	0.77	121.97	0.05
8	904	115.78	119.47	123.22	127.40	131.61	135.41	139.18	0.86	127.40	0.05
9	929	120.83	124.77	128.76	133.20	137.64	141.63	145.58	0.98	133.20	0.05
10	971	126.47	130.64	134.85	139.50	144.13	148.28	152.36	1.15	139.50	0.05
11	983	132.46	136.82	141.18	145.96	150.69	154.91	159.02	1.37	145.96	0.05
12	1007	137.82	142.27	146.70	151.51	156.23	160.41	164.46	1.63	151.51	0.05
13	765	141.58	146.06	150.47	155.23	159.87	163.94	167.87	1.91	155.23	0.04

1.78 cm for boys and 0.96 cm for girls, involving a percentage difference of 0.63% and of 0.45%, respectively (Table 6).

Discussion

During the XII Argentine Congress of Paediatrics held in the province of Tucumán, Argentina in 1963, the need for developing anthropometric tables reflecting the real paediatric situation of the country was proposed. For that purpose, the Co-ordinating Committee for the Study of Child Growth and Development of Argentina was created, with a main centre in the city of La Plata, province of Buenos Aires, and peripheral centres in other provinces, namely San Juan, Córdoba, Salta and Chubut. From that collaborative experience, data of 0–12 year old children were gathered and used to build the standards of the Argentina population growth which are currently employed (Lejarraga & Orfila, 1987; Lejarraga et al., 2009). Nevertheless, these age group data came only from two prosperous provinces of Argentina—Buenos Aires (Cusminsky et al., 1966, 1974, 1980) and Córdoba (Funes Lastra et al., 1975)—and were collected between 1965–1970.

Regarding the international WHO reference (De Onis et al., 2007), data of children aged 5–13 years old were obtained from national health surveys conducted in the US in

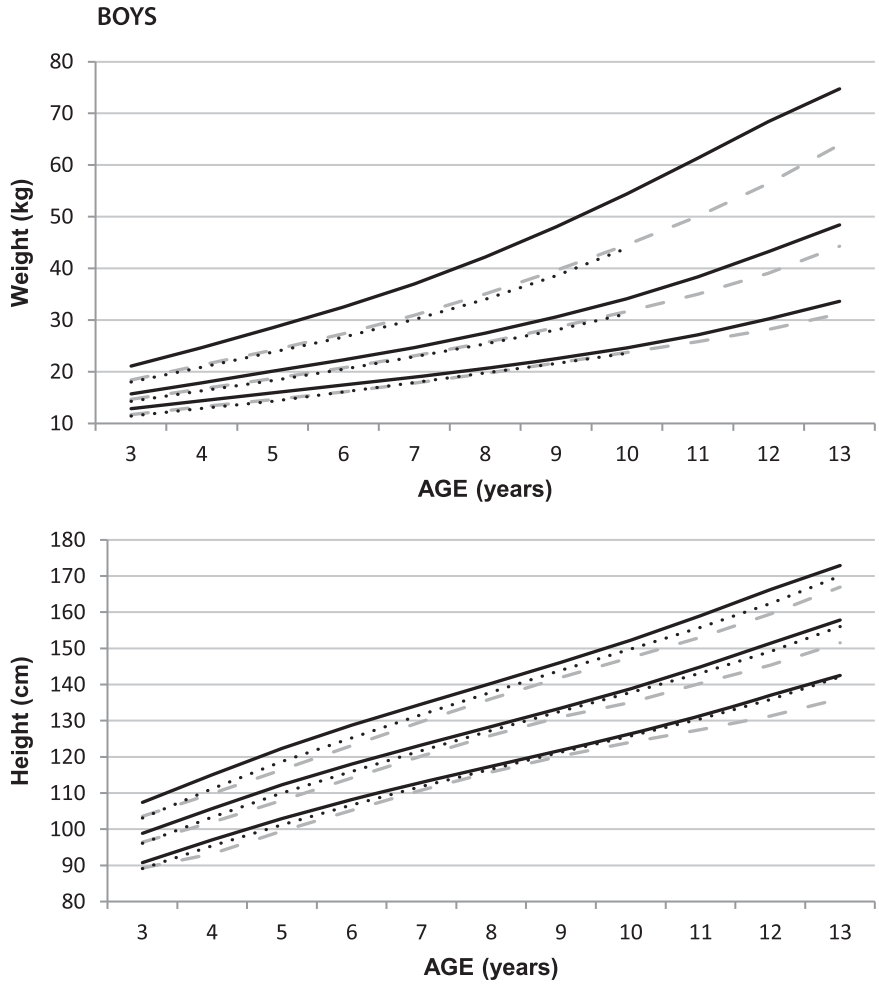

Figure 1. Comparison of weight-for-age and height-for-age percentiles 3, 50 and 97 in boys. —— Present study; – – – National reference; · · · International reference.

Cycles II (6–11 years) and III (12–17 years) of the Health Examination Survey (HES) and in Cycle I (0–74 years) of the Health and Nutrition Examination Survey (HANES). Finally, 0–5 year data came from a multi-national longitudinal study and included children from Pelotas (Brazil), Accra (Ghana), Delhi (India), Oslo (Norway), Muscat (Oman) and Davis (USA). Data of the group above 5 years were recorded before 1971 (De Onis et al., 2007) and for the group below 5 years old between 1997–2003 (WHO, 2006). In 2007, according to Resolution N°. 1376/2007, the Ministerio de Salud de la Nación Argentina (2007) adopted the WHO child growth as a new tool for anthropometric assessment in Argentinean children between 0–5 years.

Therefore, after comparison with the national and international references, our study shows that the analysed Argentinean children were taller and heavier. The observed differences could be attributed primarily to the constitution of the samples and the statistical methods employed. Thus, it is important to remember that the sample was formed by data from all over the country, including four of its five sanitary regions, making it representative of the ethnic diversity of the current population in Argentina and that the anthropometric data was collected between 2003–2008, thus becoming the most recent one.

The magnitude of W/A percentiles could certainly reflect the effects of the obesity epidemic in Argentinean schoolchildren. Nevertheless, since H/A percentiles were also higher than those of the national reference in most age groups, the distribution of body weight may have also reflected a greater body mass due to its genuine increase and not at the expense of fat mass.

Other comparative studies with Argentinean schoolchildren are consistent with the discrepancies found in the present research. In a cross-sectional study of 1470 schoolchildren from the city of La Plata (Buenos Aires), H/A distribution was shifted to the left with respect to the international reference (NHANES I and II) and to the right with respect to the national one, while the weight-for-height (W/H) overlapped in both (Oyhenart & Orden, 2005). Similar results were found in another study that used the LMS method to calculate W/A and H/A percentiles in 9082 children aged 0–5 years from different cities of Jujuy province (Alfaro et al., 2008). These percentiles were compared with those published by the CDC (Kuczmarski et al., 2002) and WHO (2006), showing that, in general, they were lower than those of both references. In other research with schoolchildren between 4–16 years of age of the same province, the authors found discrepancies against the CDC reference that ranged between 0.1–3.7% for positive values and −0.5 and −2.2% for negative ones (Alfaro et al., 2004).

All the information above raises the need to establish a new national reference, paying special attention to study design, selection criteria of the sample, measures to be taken and statistical treatment of the data. The selected sample

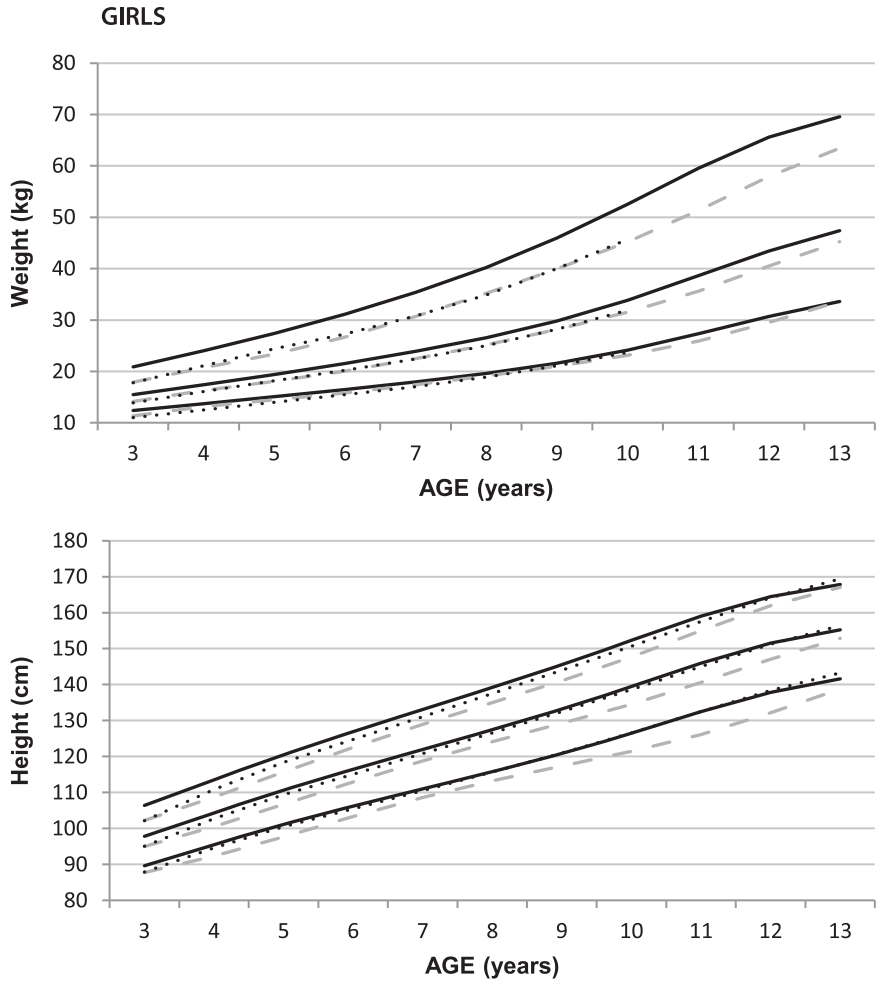

Figure 2. Comparison of weight-for-age and height-for-age percentiles 3, 50 and 97 in girls. —— Present study; – – – National reference; · · · International reference.

Table 5. Absolute (kg) and percentage (%) difference of percentiles (P) of weight-for-age with the international and national references, by sex and age.

	International reference						National reference					
	P3		P50		P97		P3		P50		P97	
Age	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
Boys												
3	−1.47	−5.27	−1.43	−4.13	−3.12	−7.18	−1.14	−4.04	−1.09	−3.10	−2.73	−5.99
4	−1.50	−4.77	−1.57	−3.99	−3.76	−7.18	−1.14	−3.58	−1.14	−2.88	−3.35	−6.31
5	−1.66	−4.76	−1.81	−4.07	−4.75	−7.90	−1.59	−3.76	−1.45	−3.25	−4.39	−7.23
6	−1.31	−3.39	−1.81	−3.67	−5.84	−8.59	−1.30	−3.37	−1.56	−3.15	−5.19	−7.55
7	−1.03	−2.43	−1.79	−3.27	−6.88	−8.94	−1.15	−2.72	−1.61	−2.93	−6.02	−7.72
8	−0.86	−1.85	−2.07	−3.40	−8.20	−9.38	−1.40	−3.04	−1.77	−2.90	−7.14	−8.05
9	−0.93	−1.83	−2.49	−3.68	−9.44	−9.50	−0.83	−1.63	−1.99	−2.93	−8.41	−8.35
10	−1.02	−1.83	−2.45	−3.92	−10.54	−9.34	−0.86	−1.55	−2.45	−3.26	−9.85	−8.67
11	–	–	–	–	–	–	−1.26	−2.16	−3.34	−3.94	−11.30	−8.84
12	–	–	–	–	–	–	−2.03	−3.03	−4.19	−4.41	−11.95	−8.33
13	–	–	–	–	–	–	−2.41	−3.22	−4.13	−3.87	−10.81	−6.78
Average	−1.22	−3.26	−1.92	−3.77	−6.57	−8.50	−1.37	−2.91	−2.25	−3.33	−7.37	−7.62
Girls												
3	−1.34	−5.70	−1.56	−4.62	−3.07	−6.91	−1.02	−3.73	−1.31	−3.84	−2.94	−6.60
4	−1.23	−4.08	−1.30	−3.37	−2.91	−5.61	−0.56	−1.80	−1.07	−2.75	−3.28	−6.38
5	−1.08	−3.22	−1.21	−2.79	−2.98	−5.01	−0.59	−1.74	−1.33	−3.09	−4.02	−6.90
6	−0.97	−2.63	−1.36	−2.82	−3.82	−5.68	−0.63	−1.70	−1.49	−3.10	−4.47	−6.74
7	−0.97	−2.40	−1.53	−2.87	−4.58	−6.02	−0.58	−1.42	−1.18	−2.72	−4.71	−5.81
8	−0.70	−1.58	−1.58	−2.66	−5.33	−6.17	−0.49	−1.10	−1.38	−2.32	−5.04	−5.81
9	−0.50	−1.02	−1.62	−1.97	−5.95	−6.02	−0.62	−1.26	−1.66	−2.49	−6.00	−6.08
10	−0.45	−0.82	−1.94	−2.56	−6.84	−6.05	−1.02	−1.88	−2.32	−3.09	−5.35	−6.55
11	–	–	–	–	–	–	−1.42	−2.32	−2.97	−3.51	−8.23	−6.46
12	–	–	–	–	–	–	−1.14	−1.65	−2.93	−3.03	−7.65	−5.38
13	–	–	–	–	–	–	+0.01	+1.29	−2.17	−2.04	−6.12	−3.99
Average	−0.90	−2.68	−1.51	−2.96	−4.43	−5.93	−0.73	−1.57	−1.80	−2.91	−5.25	−6.06

Table 6. Absolute (cm) and percentage (%) difference of percentiles (P) of height-for-age with the international and national references, by sex and age.

	International reference						National reference					
	P3		P50		P97		P3		P50		P97	
Age	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
Boys												
3	−1.68	−0.81	−2.71	−1.21	−4.32	−1.78	−1.49	−0.72	−2.40	−1.07	−3.90	−1.60
4	−1.60	−0.72	−2.30	−0.98	−3.82	−1.47	−2.43	−1.10	−3.09	−1.29	−4.44	−1.71
5	−1.75	−0.74	−2.24	−0.87	−3.64	−1.31	−3.49	−1.49	−4.31	−1.70	−5.93	−2.15
6	−1.45	−0.58	−1.99	−0.73	−3.54	−1.22	−2.94	−1.20	−3.84	−1.44	−5.64	−1.94
7	−1.06	−0.40	−1.54	−0.55	−2.80	−0.93	−2.12	−0.82	−3.00	−1.07	−4.84	−1.59
8	−0.82	−0.30	−1.09	−0.37	−2.44	−1.76	−1.64	−0.61	−2.47	−0.84	−4.28	−1.35
9	−0.51	−0.18	−0.87	−0.28	−2.19	−0.65	−1.61	−0.99	−1.77	−0.79	−4.15	−1.25
10	−0.54	−0.19	−1.03	−0.32	−2.42	−0.69	−2.30	−0.80	−3.06	−0.97	−4.73	−1.37
11	−0.90	−0.29	−1.76	−0.53	−3.23	−0.89	−3.88	−1.30	−4.59	−1.40	−6.03	−2.84
12	−1.17	−0.37	−2.32	−0.67	−3.82	−1.01	−5.71	−1.85	−6.07	−1.78	−6.78	−1.81
13	−0.42	−0.13	−1.82	−0.50	−2.93	−0.74	−6.40	−2.00	−6.03	−1.77	−5.97	−1.52
Average	−1.08	−0.43	−1.78	−0.63	−3.19	−1.04	−3.09	−1.17	−3.69	−1.28	−5.15	−1.73
Girls												
3	−1.73	−0.84	−2.74	−1.23	−4.18	−1.74	−1.86	−0.91	−2.82	−1.27	−4.11	−1.71
4	−0.85	−0.38	−1.62	−0.68	−2.72	−1.05	−2.51	−1.16	−3.12	−1.32	−4.05	−1.58
5	−0.56	−0.24	−1.20	−0.47	−2.05	−0.74	−3.36	−1.47	−3.90	−1.56	−4.75	−1.75
6	−0.75	−0.31	−1.36	−0.51	−2.15	−0.74	−2.88	−1.19	−3.48	−1.32	−4.36	−1.52
7	−0.58	−0.23	−1.17	−0.42	−2.00	−0.66	−2.45	−0.97	−3.18	−1.14	−4.14	−1.37
8	−0.08	−0.03	−0.80	−0.27	−1.68	−0.52	−2.54	−0.91	−3.24	−1.13	−4.21	−1.33
9	+0.17	+0.06	−0.70	−0.23	−1.58	−0.47	−3.48	−1.27	−3.98	−1.32	−4.49	−1.36
10	+0.13	+0.04	−0.90	−0.47	−1.66	−0.47	−5.05	−1.77	−4.94	−1.56	−4.65	−1.35
11	+0.04	+0.01	−0.96	−0.29	−1.52	−0.42	−6.32	−2.12	−5.40	−1.63	−4.04	−1.12
12	+0.58	+0.18	−0.31	−0.09	−0.36	−0.09	−5.69	−1.76	−4.48	−1.30	−2.53	−0.67
13	+1.28	+0.52	+1.17	−0.33	+1.53	+0.39	−2.78	−0.86	−2.32	−0.65	−0.85	−0.22
Average	−0.22	−0.11	−0.96	−0.45	−1.67	−0.59	−3.54	−1.30	−3.71	−1.29	−3.83	−1.27

should involve biological, socio-economic and cultural characteristics that reflect the different growth patterns (Baya-Botti et al., 2010; Kulaga et al., 2010; Monasta et al., 2011; So et al., 2011). This would require collaboration among different institutions concerned with human growth and development, such as universities, ministries of health and scientific societies.

Conclusion

The weight and height distribution of contemporary Argentinean schoolchildren from most regions of the country differs from that of national and international references. Since assessments of growth and nutritional status depend on the pattern to be used, it is advisable to establish a new national reference based on internationally recognized methodological criteria that adequately reflect the biological and cultural diversity of the current Argentinean populations.

Acknowledgements

The authors are grateful to Dr T. J. Cole of the Institute of Child Health, MRC Human Nutrition Research, Cambridge, UK, for the transfer of LMS software, to Mrs Estela Chaves for assistance in the preparation of tables and figures and to Adriana Di Maggio for editing the manuscript.

Declaration of interest

The economic support of this study came from Argentina: PICT 2007-01541 and PICTO 2008-00139 (Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT)); 11N/552 (Universidad Nacional de La Plata), and Spain: GCL2005 Project 05372 (Ministerio de Ciencia y Tecnología). The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

Alfaro E, Bejarano IF, Dipierri JE, Quispe Y, Cabrera G. 2004. Centilos de peso, talla e índice de masa corporal de escolares jujeños calculados por el método LMS. Arch Argent Pediatr 102:434–440.

Alfaro EL, Vázquez ME, Bejarano IF, Dipierri JE. 2008. The LMS method and weight and height centiles in Jujuy (Argentina) children. HOMO 59:223–234.

Baya-Botti A, Pérez-Cueto FJA, Vásquez Monllor PA, Kolsteren PW. 2010. International BMI-for-age references underestimate thinness and overestimate overweight and obesity in Bolivian adolescents. Nutr Hosp 25:428–436.

Bejarano IF, Quero L, Dipierri JE, Alfaro E. 2001. Crecimiento y estado nutricional infantil en San Salvador de Jujuy. Rev Arg Antrop Biol 3: 35–47.

Bergel ML, Cesani MF, Cordero ML, Navazo B, Olmedo S, Quintero F, Sardi M, et al. 2014. Valoración nutricional de escolares de tres países iberoamericanos: análisis comparativo de las referencias propuestas por la IOTF y la OMS. Nutr Clín Diet Hosp 34:8–15.

Bonthuis M, van Stralen KJ, Verrina E, Edefonti A, Molchanova EA, Hokken-Koelega AC, Schaefer F, Jager KJ. 2012. Use of national and international growth charts for studying height in European children: development of up-to-date European height-for-age charts. PLoS One 7:e42506.

Cole TJ. 1989. The British, American NCHS, and Dutch weight standards compared using the LMS method. Am J Hum Biol 1: 397–408.

Cole TJ. 1990. The LMS method for constructing normalized growth standards. Eur J Clin Nutr 44:45–60.

Cole TJ. 1994. Statistical constructs of human growth: new growth charts for old. In: Ulijaszek SJ, Mascie-Taylor CGN, editors. Anthropometry: the individual and the population. Cambridge: Cambridge Studies in Biological Anthropology. p 79–98.

Cole TJ, Green PJ. 1992. Smoothing reference centile curves: the LMS method and penalized likelihood. Statistic Med 11:1305–1319.

Cusminsky M, Castro E, De Azcona LCH, Jubany E, Mele E. 1966. Estudio longitudinal del crecimiento y desarrollo del niño en La Plata. Buenos Aires: Comisión de Investigaciones Científicas de la Provincia de Buenos Aires.

Cusminsky M, Castro E, Lejarraga H, De Azcona LCH, Rodríguez A. 1980. Tablas normales de peso, estatura y perímetro cefálico desde el nacimiento hasta los doce años de edad. Arch Argent Pediatr 74: 281–295.

Cusminsky M, Castro E, Lozano G, Lejarraga H, Spotti M, Porfiri N, Sosa Cordoba N, et al. 1974. Investigación del crecimiento y desarrollo del niño de 4 a 12 años. Buenos Aires: Ministerio de Bienestar Social, Comisión de Investigaciones Científicas de la Provincia de Buenos Aires.

Dahinten SI, Castro LE, Zavatti JR, Forte LM, Oyhenart EE. 2011. Growth of school children in different urban environments in Argentina. Ann Hum Biol 38:219–227.

De Onis M, Garza C. 1997. Time for a new growth reference. Pediatrics 100:1–2.

De Onis M, Onyango AW, Borghi E, Siyam A, Nishidaa C, Siekmann J. 2007. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 85:660–667.

Dipierri JE, Bejarano I, Alfaro E, Spione C. 1998. Rural and urban child height and its relation to geographic altitude in the province of Jujuy (Argentina). Acta Med Auxol 30:11–17.

Funes Lastra P, Agrelo F, Guita S, Chiquilito FC de, Borjadello LT de, Videla N, Foscarini C de, et al. 1975. Desarrollo de niños normales de la ciudad de Córdoba a través de una muestra representativa. Córdoba: Universidad Nacional de Córdoba.

Hermanussen M, Assmann C, Tutkuviene J. 2010. Statistical agreement and cost-benefit: comparison of methods for constructing growth reference charts. Ann Hum Biol 37:57–69.

Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, et al. 2002. 2000 CDC growth charts United States: methods and development. National Center for Health Statistics. Vital Health Stat 11:1–190.

Kulaga Z, Litwin M, Tkaczyk M, Rózdzyńska A, Barwicka K, Grajda A, Swiader A, et al. 2010. The height-, weight-, and BMI-for-age of Polish school-aged children and adolescents relative to international and local growth references. BMC Public Health 10:109.

Lejarraga H, Orfila G. 1987. Estándares de peso y estatura para niñas y niños argentinos desde el nacimiento hasta la madurez. Arch Argent Pediatr 85:209–222.

Lejarraga H, Pino M, Fano V, Caino S, Cole TJ. 2009. Referencias de peso y estatura desde el nacimiento hasta la madurez para niñas y niños argentinos: incorporación de datos de la OMS de 0 a 2 años, recálculo de percentilos para obtención de valores LMS. Arch Argent Pediatr 107:126–133.

Ministerio de Salud de la Nación Argentina. 2007. Resolución 1376/ 2007. Adopción de los patrones de crecimiento de la Organización Mundial de la Salud para niños. Ciudad Autónoma de Buenos Aires, Argentina: Ministerio de Salud de la Nacion Argentina. Available online at: www.msal.gov.ar/promin/archivos/pdf/resolucion-1376.pdf (accessed August 14, 2014).

Monasta L, Lobstein T, Cole TJ, Vignerová J, Cattaneo A. 2011. Defining overweight and obesity in pre-school children: IOTF reference or WHO standard? Obes Rev 12:295–300.

Orden AB, Torres MF, Castro L, Cesani MF, Luis MA, Quintero FA, Oyhenart EE. 2009. Physical growth in schoolchildren from Argentina: comparison with Argentinean and CDC/NCHs growth references. Am J Hum Biol 21:312–318.

Oyhenart EE, Orden AB. 2005. Diferencias en las prevalencias de desnutrición al usarse referencias nacionales e internacionales. Rev Panam Salud Publica 18:157–162.

Oyhenart EE, Dahinten SL, Alba JA, Alfaro EL, Bejarano IF, Cabrera GE, Cesani MF, et al. 2008. Estado nutricional infanto juvenil en seis provincias de Argentina: variación regional. Rev Arg Antrop Biol 10: 1–62.

Oyhenart EE, Garraza M, Bergel ML, Torres MF, Castro LE, Luis MA, Forte LM, et al. 2013. Caracterización del estado nutricional, enteroparasitosis y condiciones socio-ambientales de la población infanto-juvenil del Partido de La Plata. Rev Arg Antrop Biol 15: 47–60.

Pan H, Cole TJ. 2011. LMS chartmaker, a program to construct growth references using the LMS method. Version 2.43. Bilbao, España: Universidad del País Vasco-Euskal Herriko Unibertsitatea- The University of the Basque Country. Available online at: http:// www.healthforallchildren.co.uk (accessed November 21, 2013).

Rebato E, Rosique J, Salces I, San Martín L, Fernández R. 2002. Estudio comparativo entre el PB1 y la combinación del PB1 con el LMS en una muestra transversal de Bizkaia. Antropo 3:11–22.

So HK, Nelson EAS, Sung RYT, Ng PC. 2011. Implications of using World Health Organization growth reference (2007) for identifying growth problems in Hong Kong children aged 6 to 18 years. Hong Kong Med J 17:174–179.

Sociedad Argentina de Pediatría. 2001. Guía para la evaluación del crecimiento. Buenos Aires: Sociedad Argentina de Pediatría.

Ulijaszek SJ, Johnston FE, Preece MA. 2000. The Cambridge encyclopedia of human growth and development. Cambridge: Cambridge University Press.

Weiner JS, Lourie JA, editors. 1981. Practical human biology. London: Academic Press.

WHO. 2006. The WHO child growth standards. Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. Methods and Development. Geneva: WHO. Available online at: http://www.who.int/childgrowth/standards/ Technical_report.pdf (accessed November 21, 2013).

WMA. World Medical Association. 2001. Declaration of Helsinki. Ethical principles for medical research involving human subjects. Bull World Health Organ 79:373–374.