Body mass index, weight, and height percentiles in school-aged children from Mendoza. A comparison with the WHO reference

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ABSTRACT

Introduction. The World Health Organization (WHO) recommends the use of reference tables to monitor the growth pattern and nutritional status of children and adolescents. Body mass index (BMI), weight, and height are the most commonly used variables. The objective of this study was to estimate the BMI, weight, and height percentiles for school-aged children (2009-2011) living in the department of San Rafael (Mendoza) and compare them to the international World Health Organization reference to establish their relevance for the evaluation of the growth pattern and nutritional status of this population.

Population and methods. A cross-sectional anthropometric study was conducted in 3448 school-aged children aged 4.00 to 13.49 years. The LMS ChartMarker Pro software was used to estimate the BMI-for-age, weight-for-age, and height-for-age percentiles, by sex and age, and they were compared with the WHO curves. Besides, percentage differences (%D) were calculated to estimate the differences and their statistical significance using the Wilcoxon test.

Results. The population of boys and girls in San Rafael showed higher weight and BMI (%D ≈ 7% and 9%, respectively) percentiles, and lower height (%D ≈ 0.8%) values than WHO reference ($p < 0.05$).

Conclusion. The differences found warn about the use of the WHO reference in the school-aged population of San Rafael since it would overestimate the prevalence of overweight, obesity, and chronic malnutrition and underestimate the prevalence of acute and global malnutrition. This situation highlights the importance of having a local reference resource.

Key words: *growth and development; reference values; statistical methods; World Health Organization.*

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INTRODUCTION

Human growth and development is a dynamic and continuous process determined by heredity and influenced by environment. During this period, an individual increases in size and body shape and composition change.[1] The ability to modify the growth pattern is called plasticity, term employed to describe the phenotypical changes that occur during ontogeny in response to environmental conditions,[2] including dietary habits, socio-economic status, and place of residence.[3,4] Thus, it is assumed that patterns of population growth reflect living conditions.[5]

The World Health Organization (WHO) recommends the use of reference tables to monitor the health and well-being of populations.[6,7] Body mass index (BMI), weight, and height are the most commonly used variables to assess the physical growth and nutritional status of children and adolescents.[4] Unlike other countries, Argentina has its own reference tables that were developed based on data obtained in La Plata and Córdoba between 1960 and 1970, and on a sample obtained throughout the country in 1985.[8] Later, these tables were updated by Lejarraga and collaborators,[9] using the LMS method, which allows anthropometric data to be adjusted to obtain normalized percentiles.[10] Whereas these updates are valuable, these tables lack information about BMI, which is used to estimate overweight and obesity. For this reason, it is possible that the National Ministry of Health will continue to use the WHO international reference to conduct its surveys on child nutrition and health.[11,12]

The WHO reference assumes that boys and girls have similar growth patterns when they live in healthy environmental conditions without restrictions for growth. In 2006, this agency developed growth tables for child population from birth to 5 years of age, based on data from healthy child populations from six countries, exclusively breastfed until 6 months of age, whose mothers were non-smokers and had adequate socioeconomic conditions.[13] The WHO then reconstructed the growth pattern between the ages of 5 and 19 years, using the sample obtained by the National Center for Health Statistics (NCHS) in 1977, supported with data from the WHO Child Growth Standards and using the exponential Box-Cox power transformation method.[14]

In recent decades, the WHO reference has been adopted for growth assessment by more than 100 countries, including Argentina.[15] However, a collaborative and comparative study by Oyhenart et al.,[16] which included 18 698 schoolchildren aged 3 to 13 years living in the provinces of Buenos Aires, Catamarca, Chubut, Jujuy, La Pampa, and Mendoza, showed remarkable differences between the Argentine children and adolescents and the international reference. This study revealed that the weight and height percentiles of the local child and adolescent population were above those of the WHO. However, when analyzing separately the population of children under 5 years of age in Jujuy, Alfaro and his team reported that the height and weight were lower than those of the international reference.[17] These results make us wonder whether there are significant growth pattern differences among other Argentinean child and adolescent populations with respect to the WHO reference.[14]

As a result, the objective of this study was to estimate BMI, weight, and height percentiles of school-aged children (2009–2011) living in the department of San Rafael (Mendoza) and to compare them against the international WHO reference to establish their relevance for the evaluation of the growth pattern and nutritional status of this population.

METHODOLOGY

Field of study

The department of San Rafael, located in the province of Mendoza, had 188 018 inhabitants in 2010, distributed within the urban area and 17 districts.[18] In terms of socio-demographic characteristics, 7.9% of households had unsatisfied basic needs and 3.5% lived in critical overcrowding conditions. In terms of access to health care, 51.8% of the population had health care coverage.[19]

Design and population

During the 2009–2011 period, a cross-sectional study was conducted in 21 public schools in the department of San Rafael, within the framework of different research projects (ANPCyT, CONICET, UNLP). Schools were non-randomly selected from convenience sampling based on school enrolment. For this reason, district schools with the largest number of students were chosen; urban, peri-urban and rural populations were thereby represented.

Access to schools was managed with the authorities of the Directorate General of Schools of the province. The eligible population consisted

of boys and girls aged 4.00 to 13.49 years old attending morning and afternoon school shifts in all grades. Those students who were sick at the time of the study, those who did not have their parent´s or guardian´s written consent and those who, though they had it, refused to participate, were excluded.

For the calculation of the sample size, the total number of school-aged children in the periods in which they were measured (2009–2011) was considered, data provided by the Directorate General of Schools of the province. Considering a maximum variance assumption (p*q = 0.25) for binomial distribution, 3% resolution and 95% confidence level, the minimum sample size required was 1056 school-aged children. The sample actually surveyed was 3455 students, a number that exceeded the minimum sample size, thus ensuring the representativeness of the school population of San Rafael.

Anthropometric study

The anthropometric survey was performed by one of the authors (MG), trained in anthropometric techniques, following standardized protocols.[20] Weight and height were recorded. Weight was measured in kilograms with a digital weighing scale (TANITA UM-061) (100 g precision). The school-aged children were weighed dressed in light clothing, which was then deducted from the total weight. Height was recorded in centimeters with a vertical anthropometer (SECA 213) (1 mm precision).

In order to determine the intraobserver error, each measurement was performed twice and the agreement between both was evaluated (intraclass correlation coefficient [ICC]). ICC values higher than 0.75 were considered acceptable.[21] Then, taking weight and height values into account, the BMI [weight/height^2 (kg/m^2)] was calculated. Each participant's decimal age was estimated considering the date of birth obtained from their national identity document and the date of measurement.[22]

Data analysis

Data were grouped by age and sex. Data dispersion was analyzed and, following the criterion used by Alfaro et al.,[10] outliers were eliminated using ± 4 standard deviations as the cutoff point. This led to the withdrawal of 7 cases (0.2%), so that the final sample consisted of 3448 school-aged children (1705 boys and 1743 girls).

The LMS method developed by Cole and Cole and Green was used to calculate percentile values.[23,24]

Percentiles (P) P3, P10, P25, P50, P75, P90 and P97 corresponding to BMI-for-age, weight-for-age, and height-for-age were estimated for each sex and age interval (every 6 months). This procedure was carried out using the LMS ChartMarker Pro software, while curves were plotted using the free R 3.2.0 software.

To estimate the size of the differences between the population of San Rafael and the WHO data, the following formula was applied[25]:

Percentage difference (%D) = 100 log (reference percentile/estimated percentile). A positive sign value in the differences indicates that the WHO percentile is higher than the percentile estimated for San Rafael and a negative sign value indicates that the San Rafael percentile is higher than the WHO percentile.

Afterwards, the statistical significance of the differences was evaluated using the Wilcoxon test, considering a significance level of 5% ($p < 0.05$).

Ethical considerations

The research was conducted in accordance with the ethical standards embodied in the Nuremberg Code of 1947, the Universal Declaration of Human Rights of 1948, and the Declaration of Helsinki of 1964 and subsequent amendments, with special emphasis on Law No. 26343 on Personal Data Protection. The study was approved by the Bioethics Committee of the Latin American School of Bioethics (Escuela Latinoamericana de Bioética, CELABE).

RESULTS

BMI, weight, and height percentiles obtained for boys and girls according to age intervals are presented in *Tables 1, 2, and 3*, respectively; while the comparison of P3, P50, and P97 obtained for each variable with respect to the WHO reference and the corresponding statistical significance are shown in *Figures 1, 2, and 3*.

Percentile weight (*Figure 1*) and BMI curves (*Figure 3*) of the population of San Rafael ran above those of the WHO, in both sexes, showing significant differences in the 3 percentiles plotted. In contrast, height curves were below the WHO reference and showed significant differences, except for P97 in boys, which was slightly above the WHO reference (*Figure 2*).

Weight and BMI presented %D with a negative

Table 1. Weight percentiles (kg) for boys and girls in San Rafael

	Age		Percentile						
Boys	**(years)**	**n**	**P3**	**P10**	**P25**	**P50**	**P75**	**P90**	**P97**
	4.0	31	13.82	14.64	15.62	16.93	18.60	20.54	23.10
	4.5	86	14.52	15.42	16.49	17.93	19.78	21.94	24.83
	5.0	100	15.20	16.17	17.34	18.93	20.96	23.36	26.60
	5.5	104	15.86	16.91	18.18	19.91	22.14	24.79	28.40
	6.0	99	16.53	17.66	19.03	20.92	23.35	26.28	30.29
	6.5	74	17.25	18.47	19.95	22.00	24.67	27.89	32.35
	7.0	102	18.04	19.36	20.98	23.21	26.14	29.70	34.69
	7.5	103	18.91	20.35	22.10	24.54	27.76	31.72	37.30
	8.0	89	19.85	21.40	23.31	25.98	29.53	33.92	40.19
	8.5	92	20.86	22.55	24.63	27.55	31.46	36.34	43.37
	9.0	116	21.92	23.75	26.01	29.21	33.51	38.92	46.79
	9.5	101	22.99	24.97	27.43	30.92	35.64	41.62	50.42
	10.0	106	24.08	26.22	28.88	32.67	37.83	44.42	54.22
	10.5	118	25.17	27.46	30.33	34.43	40.05	47.28	58.14
	11.0	110	26.25	28.70	31.78	36.21	42.31	50.20	62.14
	11.5	88	27.32	29.95	33.25	38.03	44.61	53.18	66.23
	12.0	84	28.38	31.20	34.74	39.88	46.98	56.25	70.41
	12.5	79	29.44	32.45	36.25	41.76	49.41	59.40	74.69
	13.0	23	30.48	33.69	37.75	43.65	51.86	62.61	79.07
Girls									
	4.0	37	12.96	13.98	15.21	16.71	18.58	21.00	24.27
	4.5	77	13.61	14.70	16.02	17.63	19.66	22.32	25.96
	5.0	71	14.25	15.41	16.81	18.54	20.74	23.65	27.70
	5.5	96	14.89	16.13	17.62	19.48	21.86	25.04	29.55
	6.0	94	15.59	16.90	18.50	20.50	23.09	26.59	31.64
	6.5	99	16.38	17.78	19.49	21.66	24.49	28.37	34.07
	7.0	99	17.24	18.74	20.60	22.95	26.05	30.36	36.85
	7.5	110	18.14	19.76	21.76	24.31	27.71	32.49	39.82
	8.0	102	19.09	20.83	22.99	25.76	29.47	34.75	42.96
	8.5	121	20.08	21.95	24.29	27.29	31.33	37.12	46.19
	9.0	109	21.12	23.14	25.67	28.93	33.32	39.60	49.46
	9.5	118	22.21	24.41	27.15	30.69	35.44	42.21	52.72
	10.0	101	23.36	25.75	28.73	32.57	37.70	44.92	55.94
	10.5	113	24.55	27.17	30.42	34.59	40.10	47.76	59.15
	11.0	104	25.81	28.68	32.23	36.75	42.67	50.74	62.37
	11.5	95	27.11	30.27	34.15	39.04	45.36	53.82	65.62
	12.0	105	28.43	31.90	36.14	41.42	48.16	56.96	68.87
	12.5	72	29.73	33.54	38.16	43.85	51.00	60.13	72.11
	13.0	20	30.98	35.15	40.18	46.30	53.85	63.30	75.33

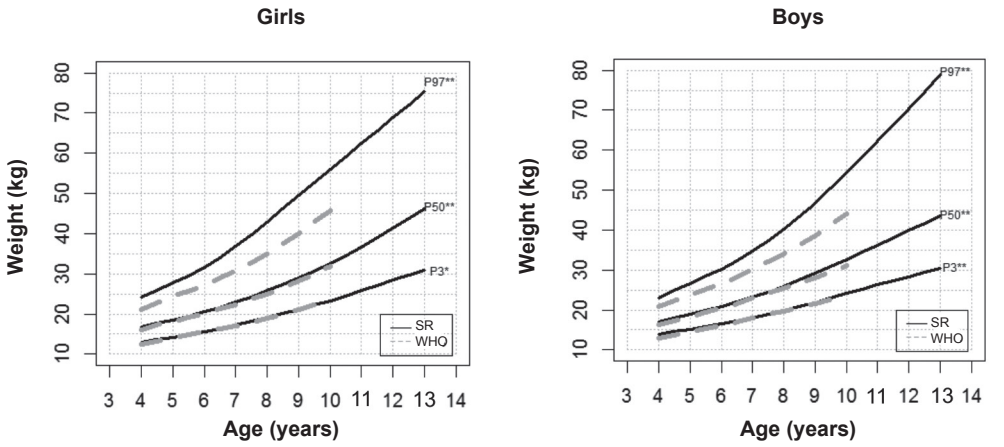
Table 2. Height percentiles (cm) for boys and girls in San Rafael

	Age		Percentile						
Boys	**(years)**	**n**	**P3**	**P10**	**P25**	**P50**	**P75**	**P90**	**P97**
	4.00	31	94.81	97.14	99.69	102.51	105.64	109.15	113.13
	4.50	86	97.36	99.81	102.48	105.41	108.63	112.21	116.21
	5.00	100	99.89	102.47	105.27	108.30	111.62	115.26	119.29
	5.50	104	102.41	105.13	108.06	111.21	114.62	118.33	122.37
	6.00	99	104.91	107.78	110.84	114.11	117.62	121.40	125.48
	6.50	74	107.34	110.36	113.55	116.95	120.57	124.42	128.55
	7.00	102	109.72	112.89	116.23	119.75	123.48	127.42	131.60
	7.50	103	112.09	115.41	118.90	122.56	126.40	130.44	134.68
	8.00	89	114.47	117.95	121.58	125.37	129.33	133.48	137.81
	8.50	92	116.89	120.52	124.29	128.21	132.30	136.55	140.98
	9.00	116	119.32	123.07	126.97	131.02	135.24	139.62	144.17
	9.50	101	121.64	125.51	129.53	133.71	138.05	142.56	147.25
	10.00	106	123.86	127.81	131.93	136.22	140.69	145.34	150.18
	10.50	118	126.00	130.04	134.25	138.65	143.24	148.03	153.04
	11.00	110	128.18	132.31	136.62	141.13	145.85	150.79	155.97
	11.50	88	130.43	134.67	139.10	143.73	148.59	153.69	159.03
	12.00	84	132.73	137.09	141.66	146.44	151.45	156.70	162.21
	12.50	79	135.06	139.56	144.27	149.21	154.37	159.78	165.45
	13.00	23	137.39	142.05	146.91	152.00	157.32	162.89	168.72
Girls									
	4.00	37	93.86	96.21	98.74	101.47	104.41	107.61	111.09
	4.50	77	96.27	98.77	101.44	104.28	107.33	110.59	114.10
	5.00	71	98.66	101.32	104.13	107.10	110.24	113.57	117.11
	5.50	96	101.07	103.89	106.85	109.94	113.18	116.59	120.16
	6.00	94	103.56	106.55	109.65	112.88	116.23	119.72	123.35
	6.50	99	106.16	109.31	112.57	115.93	119.40	122.98	126.68
	7.00	99	108.80	112.11	115.51	119.01	122.60	126.28	130.07
	7.50	110	111.42	114.86	118.39	122.01	125.72	129.51	133.40
	8.00	102	113.95	117.51	121.15	124.88	128.70	132.60	136.59
	8.50	121	116.38	120.04	123.78	127.60	131.52	135.52	139.61
	9.00	109	118.80	122.55	126.38	130.30	134.31	138.41	142.60
	9.50	118	121.29	125.13	129.06	133.08	137.19	141.38	145.67
	10.00	101	123.85	127.82	131.86	135.98	140.19	144.48	148.85
	10.50	113	126.47	130.58	134.75	138.99	143.30	147.67	152.11
	11.00	104	129.05	133.33	137.65	142.01	146.41	150.86	155.34
	11.50	95	131.53	136.01	140.49	144.97	149.46	153.96	158.46
	12.00	105	133.90	138.59	143.24	147.85	152.41	156.94	161.44
	12.50	72	136.15	141.08	145.91	150.64	155.27	159.83	164.30
	13.00	20	138.33	143.52	148.54	153.39	158.10	162.67	167.1

Table 3. BMI percentiles (kg/m²) for boys and girls in San Rafael

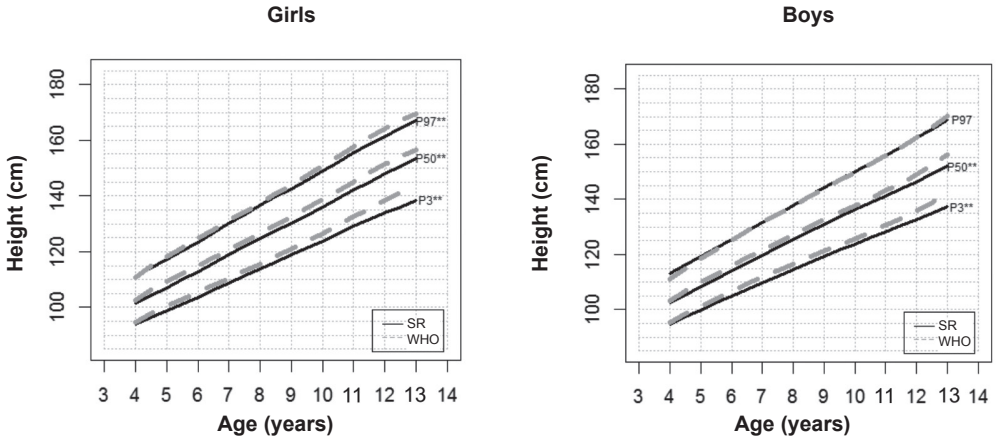
	Age		Percentile						
Boys	**(years)**	**n**	**P3**	**P10**	**P25**	**P50**	**P75**	**P90**	**P97**
	4.0	31	13.95	14.58	15.31	16.19	17.25	18.59	20.33
	4.5	86	13.85	14.50	15.26	16.16	17.28	18.69	20.59
	5.0	100	13.76	14.42	15.20	16.14	17.30	18.80	20.85
	5.5	104	13.68	14.35	15.14	16.11	17.32	18.91	21.13
	6.0	99	13.60	14.28	15.09	16.09	17.35	19.03	21.43
	6.5	74	13.57	14.27	15.10	16.13	17.44	19.22	21.83
	7.0	102	13.60	14.31	15.16	16.23	17.61	19.50	22.36
	7.5	103	13.66	14.38	15.27	16.38	17.83	19.86	23.02
	8.0	89	13.74	14.49	15.40	16.56	18.09	20.27	23.79
	8.5	92	13.85	14.62	15.56	16.77	18.38	20.73	24.66
	9.0	116	13.98	14.77	15.75	17.01	18.71	21.24	25.61
	9.5	101	14.13	14.95	15.97	17.28	19.08	21.78	26.64
	10.0	106	14.30	15.15	16.20	17.57	19.46	22.35	27.70
	10.5	118	14.46	15.33	16.43	17.85	19.84	22.90	28.72
	11.0	110	14.59	15.49	16.62	18.11	20.18	23.41	29.65
	11.5	88	14.70	15.63	16.80	18.34	20.49	23.88	30.51
	12.0	84	14.80	15.76	16.97	18.56	20.80	24.34	31.33
	12.5	79	14.90	15.89	17.14	18.79	21.12	24.80	32.14
	13.0	23	15.00	16.02	17.31	19.02	21.43	25.27	32.95
Girls									
	4.0	37	13.71	14.41	15.23	16.23	17.47	19.06	21.25
	4.5	77	13.63	14.34	15.18	16.20	17.48	19.14	21.45
	5.0	71	13.54	14.26	15.12	16.17	17.48	19.22	21.66
	5.5	96	13.46	14.19	15.06	16.14	17.50	19.31	21.90
	6.0	94	13.40	14.14	15.03	16.14	17.55	19.45	22.22
	6.5	99	13.37	14.13	15.05	16.19	17.66	19.67	22.66
	7.0	99	13.39	14.17	15.11	16.30	17.84	19.97	23.22
	7.5	110	13.42	14.22	15.20	16.44	18.05	20.32	23.85
	8.0	102	13.48	14.31	15.32	16.61	18.31	20.72	24.53
	8.5	121	13.56	14.42	15.48	16.82	18.61	21.16	25.25
	9.0	109	13.67	14.56	15.67	17.07	18.94	21.63	25.97
	9.5	118	13.78	14.71	15.86	17.33	19.29	22.10	26.63
	10.0	101	13.89	14.86	16.06	17.59	19.64	22.56	27.22
	10.5	113	14.01	15.03	16.28	17.87	20.00	23.01	27.76
	11.0	104	14.15	15.22	16.53	18.19	20.40	23.50	28.28
	11.5	95	14.33	15.45	16.82	18.56	20.85	24.02	28.82
	12.0	105	14.53	15.71	17.15	18.97	21.34	24.59	29.37
	12.5	72	14.74	15.99	17.51	19.41	21.87	25.18	29.93
	13.0	20	14.95	16.27	17.87	19.86	22.41	25.78	30.50

Figure 1. Comparison of weight-for-age percentiles in girls and boys



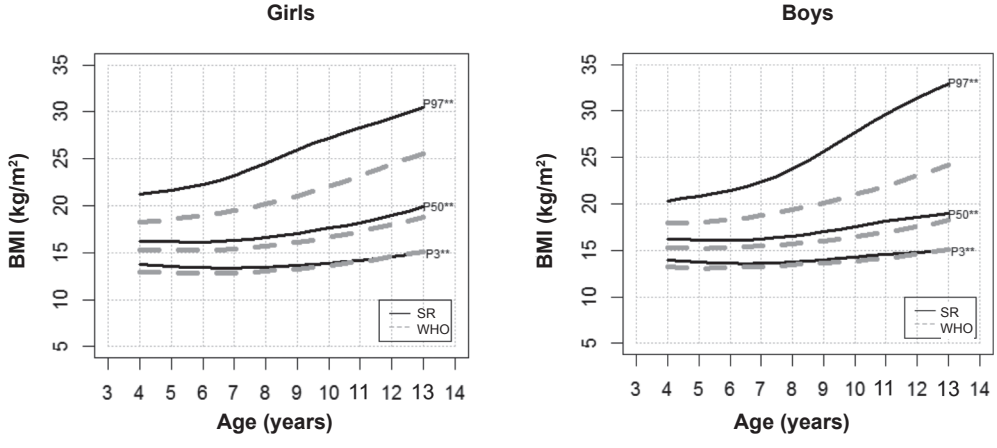
*Significance p < 0.05 *; p < 0.01.*

Figure 2. Comparison of height-for-age percentiles in girls and boys



*Significance p <0.05 *; p <0.01***

Figure 3. Comparison of body mass index (BMI)-for-age percentiles in girls and boys



*Significance p <0.05 *; p <0.01***

sign, highlighting higher values in the population studied. As for weight, the highest mean %D was recorded at P97, in both sexes. In this percentile, girls %D was 7.58% and boys, 6.52%.

These percentages showed that girls´ weight in San Rafael was 6.58 kg higher than the reference weight, while boys weight was 5.34 kg higher. As for BMI, mean %D were also higher in P97 and in both sexes. In boys it was 9.76% (5.31 kg/m^2) and in girls, 7.95% (4.28 kg/m^2). On the other hand, height showed positive differences, indicating a lower height in the population of San Rafael, except in boys´ P97. For this variable, P3 showed the greatest mean difference. In girls, the %D was 0.91%, which corresponded to 2.56 cm less than the reference, while in boys the %D was 0.77% and represented 2.15 cm less than their WHO counterparts (*Supplementary material* available at https://www.sap.org.ar/docs/publicaciones/archivosarg/2023/2672_AO_Garraza_Anexo.pdf

DISCUSSION

Results obtained show that the weight and linear growth of children in San Rafael are considerably different than the WHO pattern. While the body weight of the study population was higher, the height was lower. The size of the differences between both populations was especially remarkable in P97 body weight, which was increased by 6–7%, while in height this size was considerably lower. As a reflection of this, BMI was higher in the San Rafael school-aged children compared to the WHO reference.

It is well known that overweight and obesity have increased globally in recent years, affecting more than 340 million children and adolescents between 5 and 19 years of age.[26] In line with this trend, our results show that school-aged children from San Rafael have both BMI and body weight increased with respect to the WHO reference, coinciding with what has been reported by other authors for children living in different provinces of the country and in different socio-environmental contexts.[16,27]

It is worth mentioning that in Argentina several studies have shown a positive secular trend in excessive child weight. Thus, for the population of La Plata (Buenos Aires), increases in the prevalence of overweight and obesity of 2.5% and 3%, respectively, have been reported in the last three decades,[28] while other authors reported an approximate increase of 5% for both indicators in children of Santa Rosa (La Pampa) in the last 15 years.[29]

It has been argued that BMI and weight increase observed globally and nationally, and confirmed in the studied population, would be the result of dietary patterns characterized by a high consumption of products of low nutritional value and high calorie content, regular intake of sugary beverages, and low physical activity.[30,31] In this sense, studies aimed at getting to know the eating and physical activity habits of the school population of San Rafael will be necessary to understand why BMI and weight percentile values are higher than those of the WHO reference. What is an unequivocal fact, as shown by results of previous studies conducted in that department, is that overweight (overweight + obesity) affected 21.8% of the school population and that children living in urban areas were the most affected, with prevalences close to 26%.[32]

On the other hand, consistent with what was reported for the child population of Jujuy, the height of school-aged children in San Rafael was lower than that of the reference and with less marked differences than those for BMI and weight.[17] However, P3, usually used as a cutoff point for the diagnosis of chronic malnutrition, was the one that showed the largest gap compared with the WHO reference. In Argentina, regardless of the reference used, low height-for-age (stunting) is the most prevalent form of malnutrition.[12] According to Longhi, this type of malnutrition is one of the most important public health problems at a national level, since it has a negative impact on the high rates of infant morbidity and mortality.[33] In this regard, previous studies have shown that school-aged children in San Rafael had prevalences of chronic malnutrition close to 8%.[32,34] The lower height of this population with respect to the international reference could be due not only to interpopulation growth variation, but also to nutritional deficiencies that occurred during childhood,[34] since, although they are currently heavier with respect to the WHO values, they have not reached optimal linear growth yet.

Finally, if we consider that variables analyzed in this study are those commonly used for the diagnosis of malnutrition, overweight, and obesity, results obtained indicate that the use of the WHO reference will report higher prevalences of chronic malnutrition, overweight and obesity, and will underestimate the prevalence of acute and global malnutrition. In this sense, this study provides local reference values that could be used in the future. Finally, we emphasize the importance of specifying the criteria used for the evaluation

of the growth pattern and nutritional status in epidemiological studies, as well as comparing results by using different references.

CONCLUSIONS

School-aged children in San Rafael have higher BMI and weight and lower height than the WHO reference. In this regard, its use in this population underestimates global and acute malnutrition, and overestimates overweight and chronic malnutrition. This situation highlights the importance of having local references, developed with modern smoothing methods based on updated data. ■

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Supplementary material available at:
https://www.sap.org.ar/docs/publicaciones/archivosarg/2023/2672_AO_Garraza_Anexo.pdf

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