



## Secular changes in body size and body composition in schoolchildren from La Plata City (Argentina)

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With 3 figures and 3 tables

**Summary:** *Aim:* to analyze the secular changes in body size and composition of two cohorts of children from La Plata City, Argentina, with a 35-year follow-up. *Subjects and methods:* Cohort 1 (C1) was measured in 1969–1970 and included 1772 children (889 boys, 883 girls), and Cohort 2 (C2), measured in 2004–2005, included 1059 children (542 boys, 517 girls). Both cohorts were obtained from matching geographical areas and comprised children from 4 to 12 years. Body weight (W); Height (H); Upper arm circumference (UAC); Tricipital (TS) and Subscapular skinfolds (SS) were measured, and Body Mass Index (BMI) and muscle (UMA) and fat (AFA) brachial areas were calculated. Prevalence of overweight and obesity was estimated by IOTF. To compare C1-C2 we used a generalized linear model with log-transformed variables, and chi square test. *Results:* There were significant and positive differences between C2-C1 in W, UAC, SS, TS, and AFA. In contrast, H was not significantly different and UMA was significantly different but with negative values. The prevalence of overweight and obesity was 14.5 % and 3.8 % in C1, and 17.0 % and 6.8 % in C2. Differences between cohorts were significant for obesity. *Conclusion:* The shifts observed for soft tissues – positive trend for fat and negative for muscle area – occurring without changes in height lead us to suppose that in these three decades, La Plata's population has experienced deterioration in living conditions and important changes in their lifestyle, such as an increased consumption of energy-dense foods and sedentary habits.

**Key words:** secular trend, weight, height, subcutaneous skinfolds.

## Introduction

A secular trend is defined as a tendency for biological changes occurring between subsequent populations. Such a trend can be positive or negative; the former is characterized by an acceleration of growth and earlier maturation leading to larger final body sizes (Poplawska et al. 2006). However, some populations have experienced negative secular trends or no trends at all (Malina 1990, Hauspie et al. 1997).

Studies of living and past populations that began more than two centuries ago have revealed changes in human growth patterns. The short time ranges involved (in the

order of a few generations or a single one) indicate that those ‘secular changes’ or ‘secular trends’ are likely to result not from alterations in the genetic constitution of populations, but from the environment in which their growth takes place (Eveleth & Tanner 1990, Castilho & Lahr 2001). Thus, secular changes were prominent in the 20<sup>th</sup> century (especially after World War II) when they were expressed as a steady increase in mean height and weight of European and US populations (van Wieringen 1986). Most reports have focused on generation changes in height and body mass (Freedman et al. 2006, Malina et al. 2010, Kryst et al. 2012, Sun et al. 2012). Nevertheless, and according to Hermanussen et al. (2010), the so-called secular trend in human growth is not a consistent and homogeneous event that takes place uniformly affecting height, weight, body shape, various circumferences, and other anthropometric characters. In fact, this trend has exhibited distinctly dissimilar dynamics in these various traits during the economic transition over the past 150 years.

On the other hand, overweight or obesity affects two in three American adults and one in three of their children (Sun et al. 2012). The prevalence of overweight among adults and children has increased over the last few decades in the US (Flegal et al. 2010), Canada (Tremblay & Willms 2000), the UK (Chinn & Rona 2002, Stamatakis et al. 2005), and Japan (Yoshinaga et al. 2002, Matsushita et al. 2004) among other developed countries, as well as in the developing world (de Onis & Blössner 2000, Rössner 2002, Durán et al. 2006, Stanojevic et al. 2008). Accordingly, obesity is now a common problem worldwide which has doubtlessly increased in recent years (Lobstein et al. 2004, Wells 2010), and represents in itself a risk factor for chronic diseases such as hypertension, dyslipidemia, type 2 diabetes, cardiovascular disease, sleep apnea, musculoskeletal disorders and some cancers (Rössner 2002).

Although adipose tissue is probably the component of overweight responsible for increasing disease risk, most studies of secular trends have focused solely on indices of weight and height (Freedman et al. 1997). However, some evidence suggests that skinfolds may be more sensitive than the body mass index for detecting excess adiposity (Marshall et al. 1991, Sardinha et al. 1999, Sarria et al. 2001, Daniels 2009, Bibiloni et al. 2013). This is to be expected because skinfolds are more directly associated to the presence of subcutaneous fat than the body mass index (Norgan 1991, Bedogni et al. 2003). In Argentina, little is known about the secular trends, especially with relation to fatness. In order to investigate this phenomenon, we analyze the secular pattern in body size and composition of two cohorts of children from La Plata City (Argentina) with a 35-year follow-up.

## Methods

### Study area

La Plata is the capital city of the Province of Buenos Aires, Argentina, and is located in the northern area. The city is an administrative district situated just a few kilometers away from Buenos Aires City, with an area of 926 km<sup>2</sup> (34° 55' S, 57° 17' W; and 24 m a.s.l.). Its political boundaries are: to the NE, the Departments of Ensenada and Berisso, to the NW, Berazategui and Florencio Varela, to the SW, San Vicente and Coronel Brandsen, and to the SE, Magdalena. The two samples compared in the present study were located within the foundation area of La Plata (Fig. 1).

The first one or first cohort (C1) was obtained in the period 1969–1970, the second cohort (C2) spanned over the period 2004–2005. According to the Censo Nacional de Población y

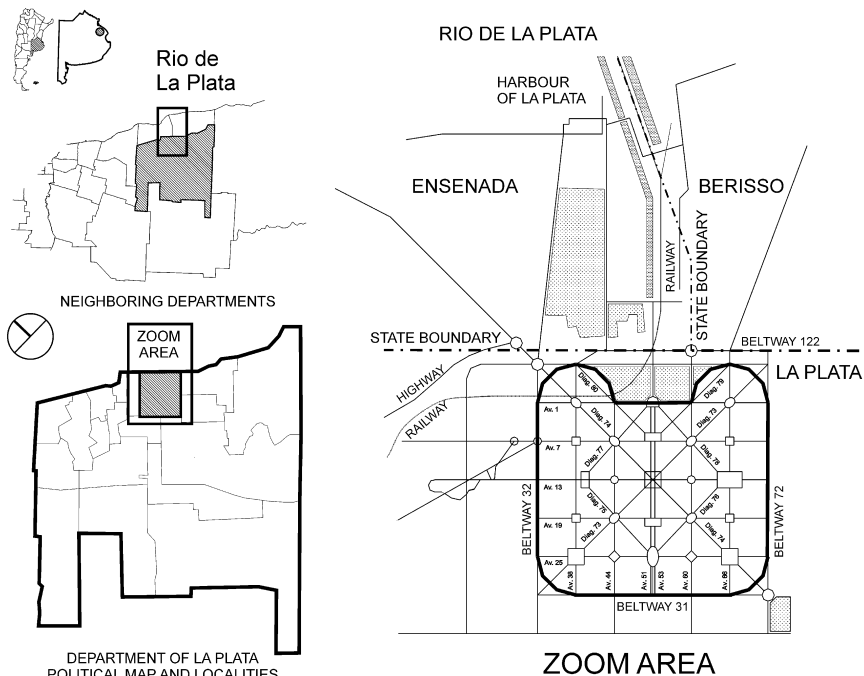


Fig. 1. Geographical location of the studied area.

Vivienda (National Census of Population and Housing), in 1970 the foundation town area housed 198,470 people, while in 2001 it held a population of 186,524. Given the importance of socio-economic factors in the process of human growth, it is necessary to consider the impact of these factors over the time period analyzed. From this viewpoint, La Plata City shows predominance of service sector employment (transport, communications, trade, housing, finance and other services), with a primary sector (agricultural exploitation) of some importance and an increasing secondary sector (industrial activity). In 1970, industrial activity comprised national-level industries that were mainly established in the neighboring districts of Berisso and Ensenada and contributed to 80 % of the industrial employment. In the early 80s, the closure of some of these major industries produced poverty and unemployment (de Terán & Morosi 1981).

## Sample and data collection

Data from two cross-sectional studies were used. The first cohort (C1) included 1772 children (889 boys and 883 girls) aged 4 to 12. They were measured in 1969–1970 through a stratified random survey of households by Cusminsky et al. (1974).

From a socio-economic perspective, it is possible to note that when the father jobs were analyzed, 52 % of them reported working in a formal employment. The self-employment option comprised 14 %, whereas 3 % of them had an informal job. With regard to educational attainment, it was observed that 45 % and 46 % of fathers and mothers, respectively, completed elementary education. Similarly, a difference was hinted when comparing the high school level, completed by 16 % of fathers and 21 % of mothers, and the largest difference was recorded at the higher education level, completed by 15 % of fathers and only 5 % of mothers.

In relation to the type of materials used to build houses, we found that 76 % was fired brick masonry, 19 % was low quality prefab and 1 % corresponded to makeshift materials (Cusminsky et al. 1974).

The second cohort (C2) was sampled in 2004 and 2005, and included 1059 children (542 boys and 517 girls) aged 4 to 12 who attended schools located in the same geographical area from which the first cohort was sampled (Fig. 1, Table 1).

The C2 socio-economic status in relation to the job revealed that 41 % of fathers and 30 % of mothers had formal employment; 11 % and 3 % were unskilled workers; 11 % and 8 % were autonomous workers; and 22 % and 10 % had informal jobs, respectively. Finally, 4 % of fathers and 37 % of mothers were unemployed.

The analysis of the educational attainment of parents, in C2, showed differences in the three segments of formal education. Thus, 52 % of fathers and 47 % of mothers had completed elementary school and the difference decreased at high school level (23 % of fathers and 26 % of mothers). Finally, the difference was accentuated at higher education level, completed by 8 % of fathers and 13 % of mothers.

Regarding the houses building materials, 64 % was fired brick masonry, 9 % was low quality prefab, 21 % was galvanized steel sheet and wood, and 3 % corresponded to makeshift materials. On the other hand, 23 % of the population received public assistance in the form of financial support and 8.7 % in the form of nutritional support from the government (Oyhenart et al. 2013).

Children of both samples were measured close to their respective birthdays ( $\pm 30$  days of the date of birth). According to this, for example, we assigned the age of 4 years to all children aged between 3 years and 11 months and 4 years and 1 month. The following variables were measured by standardized techniques (Jelliffe 1966).

Body weight (W) (kg) was measured on a scale (accuracy 100 g) with the subjects lightly clothed (the weight of clothes was then subtracted); Height (H) (cm) was measured using a portable vertical stadiometer (accuracy 1 mm); Upper arm circumference (UAC) (cm) was measured using an inextensible tape measure (accuracy 1 mm) on the left arm at the level of the tricipital skinfold. Tricipital skinfold (TS) (mm) and Subscapular skinfold (SS) (mm) were measured with a constant pressure caliper (accuracy 1 mm), the first one on a point half-way down the left arm, between the tip of the acromion process of the scapula and the olecranon process of the ulna; and the second one just below and laterally to the angle of the left scapula.

Body-mass index (BMI) was calculated as weight (kg) divided by the height squared ( $\text{m}^2$ ), and children were classified as overweight or obese according to the cut-off points proposed by the International Obesity Task Force (IOTF) (Cole et al. 2000).

Upper arm muscle area (UMA) and upper arm fat area (AFA) were estimated on the basis of total area (TA) according to the following equations (Frisancho 2008):

$$TA = [(UAC^2)/(4*\pi)]$$

$$UMA = [UAC - (TS*\pi)]^2/(4*\pi)$$

$$AFA = (TS-UMA)$$

## Statistical analysis

Collected data were summarized by means of descriptive statistics (mean and standard deviation). To compare anthropometric values corresponding to both cohorts – C1 and C2 – we applied a generalized linear model (GLM) to the log-transformed variables. Prevalence of overweight and obesity was calculated and then compared between cohorts by Chi squared test.

For graphical comparisons, mean values were standardized by Percent Differences between Means (PDM%). This standardization method reduces any difference to a percent value which is not affected by the magnitude of the variables. Percent Differences between Means were calculated as follows:

$PDM (\%) = 100 * [(X_2 - X_1) / X_2]$ .

For between-cohort comparisons:  $X_1$  = mean values of C1 and  $X_2$  = mean values of C2. All statistical procedures were carried out using R software (2.15.1).

## Results

Mean and standard deviation of measured and calculated variables for each cohort are presented in Table 1.

The linear model showed significant differences ( $C2 > C1$ ) of W, UAC, SS, TS and AFA. Differences were significant for UMA ( $C2 < C1$ ), and not significant for H. Sex (boys-girls) differences were statistically significant only for SS, TS, AFA (negative values) and UMA (positive value). The age factor showed significant differences with positive values in all the analyzed variables. Finally, the interactions between factors were not significant (Table 2).

Body weight showed PDM positive values among C2 and C1 at 5, and 7–12 years in boys, and at 5–8 and 11–12 years in girls. Similar results were found for BMI, UAC, TS, SS, and AFA. Conversely, the PDM values for UMA were negative for both sexes and most ages (Figs 2 and 3).

The prevalence of overweight and obesity was 14.5 % and 3.8 % in C1, and 17.0 % and 6.8 % in C2. Differences between cohorts were significant for obesity. Also, significant secular differences, in both boy and girls, were found for obesity (Table 3).

## Discussion

Human height is determined by various endogenous factors such as genetic predisposition and hormones, as well as environmental factors, such as nutrition (Travaglini et al. 2011). Therefore, population height has long been recognized as an index of welfare (Bogin 2001, Steckel 2008). Previous studies made in Argentina reported a clear negative trend in the average stature of recruits between 1901–1910, which then showed a recovery in the early 1920s, and continued increasing until 1940 (Salvatore & Baten 1998, Salvatore 2004, Salvatore 2009, Salvatore 2010). In addition, a positive secular trend in the height of adolescent school children was reported for the period 1938–1981 (Lejarraga 1986) and for male recruits during 1987 and 1992–1993 (Lejarraga et al. 1991, Andrade et al. 1999). Similarly, in a previous work undertaken in 2003 on school children from La Plata aged 8 to 14, Oyhenart & Orden (2005) reported that the height-for-age distribution was skewed to the right as compared with the Argentine reference values, suggesting a possible secular trend. Nevertheless, in the present study we found that boys and girls did not show differences in mean height with respect to their peers measured 35 years before.

It is well established that secular growth trends depend upon environmental and socio-economic factors (Cole 2003). While in various developed countries, improvements in socio-economic conditions and lifestyle have led to positive growth trends in the 20<sup>th</sup> century (Fredriks et al. 2000), in other countries physical growth has reached a plateau, suggesting that the full genetic potential has been achieved and/or that socio-economic conditions have ceased to improve (Krawczynski et al. 2003). On the other hand, Malina et al. (2004) reported that secular trends in height have stopped in many developed countries while body weight has continued to increase,

**Table 1.** Sample, variables and descriptive statistics (mean – M; and standard deviation – SD) according age(\*) and sex by cohort (C) 1 and 2.

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(\*) The age correspond to birthdays ± 30 days.

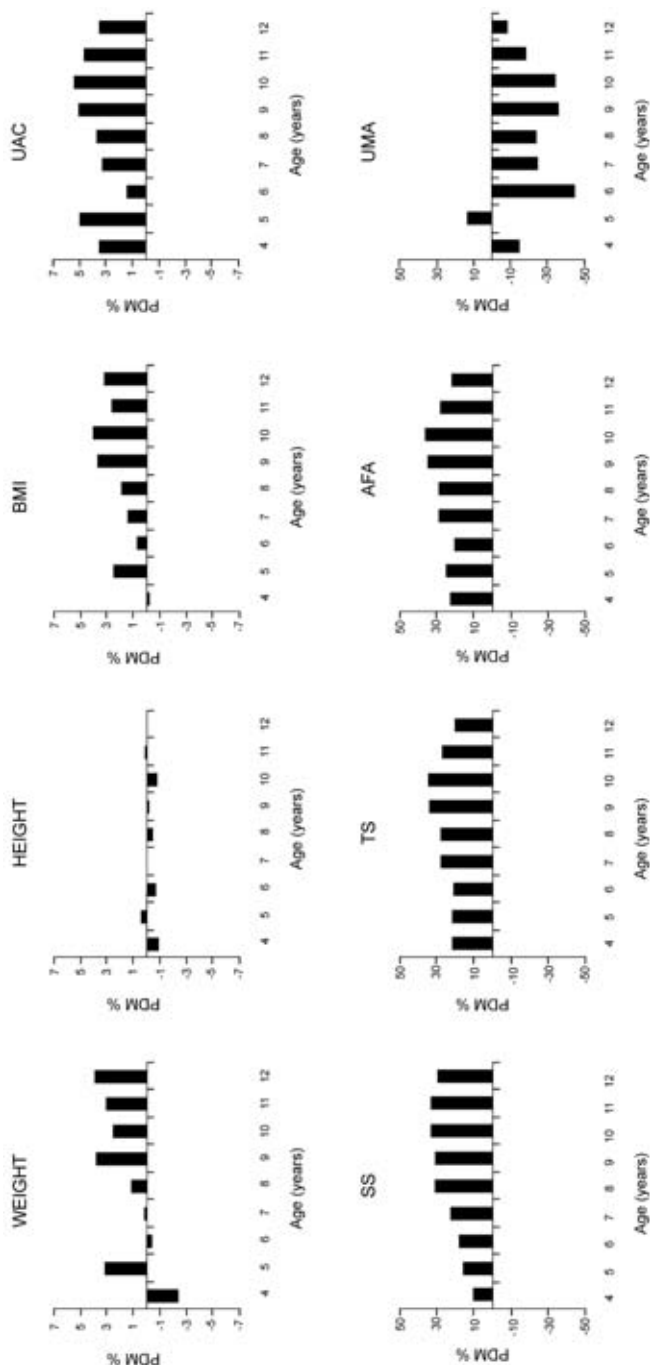
Table 2. Generalized Lineal Model for cohort, sex and age differences.

	Weight			Height			BMI			UAC		
	Estimate	t	p	Estimate	t	p	Estimate	t	p	Estimate	t	p
Intercept	2.36	199.18	**	4.46	1459.10	**	2.66	300.61	**	4.07	2241.25	**
Cohort	0.01	1.97	*	- 0.01	- 1.40	ns	0.02	3.60	**	0.01	8.02	**
(C2-C1)												
Sex	- 0.01	- 1.62	ns	- 0.01	- 0.74	ns	- 0.01	- 1.66	ns	- 0.01	- 0.82	ns
(Boys-												
Girls)												
Age	0.11	86.27	**	0.05	134.07	**	0.02	22.89	**	- 0.01	- 49.06	**

Table 2. Continued.

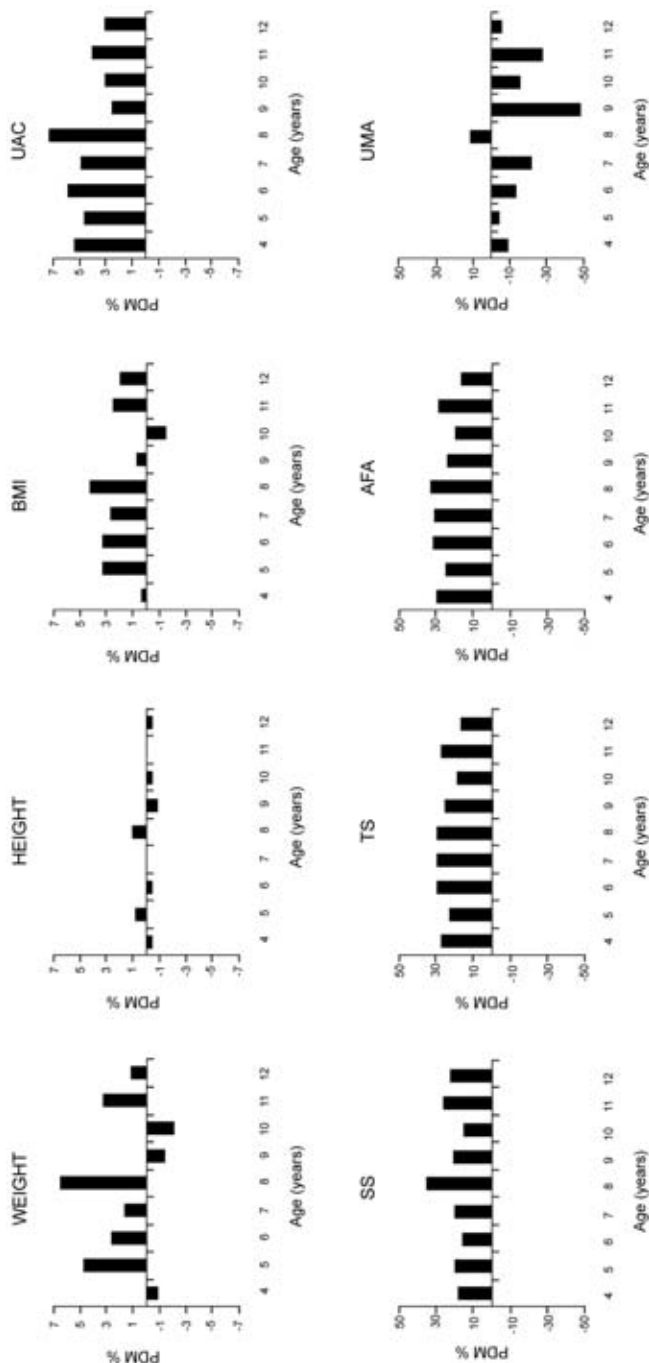
	TS			SS			AFA			UMA		
	Estimate	t	p	Estimate	t	p	Estimate	t	p	Estimate	t	p
Intercept	1.87	83.09	**	1.26	43.48	**	1.44	54.07	**	2.44	209.26	**
Cohort	0.30	22.84	**	0.22	13.27	**	0.31	20.23	**	- 0.04	- 5.80	**
(C2-C1)												
Sex	0.13	10.22	**	0.14	8.61	**	0.12	8.04	**	- 0.05	- 7.08	**
(Boys-												
Girls)												
Age	0.04	16.17	**	0.07	21.10	**	0.08	25.28	**	0.07	51.17	**

\* $p < 0.05$ , \*\* $p \leq 0.01$ , ns = non significant



**Fig. 2.** Percent Differences between Means (PDM) of measured and calculated variables in boys. Comparisons between C2 and C1 cohorts.





**Fig. 3.** Percent Differences between Means (PDM) of measured and calculated variables in girls. Comparisons between C2 and C1 cohorts.

**Table 3.** Prevalence (%) of overweight and obesity, and differences between C1 and C2 (Chi squared test  $\chi^2$ ).

	Total sample				Boys				Girls			
	C1	C2	$\chi^2$	<i>p</i>	C1	C2	$\chi^2$	<i>p</i>	C1	C2	$\chi^2$	<i>p</i>
Overweight	14.5	17.1	3.212	ns	13.1	15.9	2.224	ns	16.0	18.2	1.178	ns
Obesity	3.8	6.8	12.991	**	3.8	6.1	3.88	*	3.7	7.6	9.74	**

\**p* < 0.05, \*\**p* ≤ 0.01

resulting in a secular positive trend in overweight and obesity as indicated by changes in BMI. Furthermore, a study of children and adolescents conducted in Germany showed changes in subscapular and tricipital skinfolds thickness, interpreted as a clear gain in adiposity across time (Kromeyer-Hauschild et al. 2012). Accordingly, we observed a strong positive secular change in body weight, subscapular skinfold, and upper arm fat area, resulting in an increased upper arm circumference. Additionally, we observed a negative secular trend in upper arm muscle. As shown in Figures 2 and 3, while the mean value of tricipital and subscapular skinfolds underwent increases of 26 % and 23 % respectively, the muscle area decreased by 18 %.

Secular changes in energy intake and expenditure are assumed to underlie the obesity epidemic (Moushira et al. 2011). The transition from an economy centrally planned to a free market economy in the socialist countries produced large changes in all aspects of population's life. In this sense, Russia is one of the countries that experienced this transition and showed a severe increase in obesity and non-communicable diseases. Obesity increased from 20.3 % in 1994 to 28 % in 2004. The main determinants of obesity, among others, were the caloric intake in the diet, income, smoking habits, gender and educational level (Huffman & Rizov 2007). Also, in low-income countries, changes occurring in the structure of diet, physical activity, and obesity are greater than ever experienced before. In fact, de Onis & Blössner (2000) reported a rapid change in dietary patterns and lifestyles occurring in many developing countries where obesity rate increases among children. Data from Brazil and Chile are a good example. In Brazil, the prevalence of overweight in children and adolescents aged 6–18 years changed from 4.1 % to 13.9 % between the 1970s and 1990s; in Chile, two extensive surveys carried out between 1987 and 2000 also showed a significant increase in excess of weight, from 12 % to 26 % in boys and from 14 % to 27 % in girls (Lobstein et al. 2004). In Argentina, studies of secular trends in overweight and obesity are scarce. One of them took place in the Province of Jujuy, in a child population (4–10 years) who lives at 1259 m a.l.s. The authors reported increments of overweight (5 % in boys and 3.2 % in girls) and obesity (4 % in boys and 2.2 % in girls) between 1995 and 2000 (Bejarano et al. 2005). On the other hand, Orden et al. (2013) reported an increase of excess of weight between 1997–2005/2007 in children aged 6–12 years from the Province of La Pampa (4.4 % in boys and 5.9 % in girls). According to this, our study also showed an increment of overweight (2.8 % in boys and 2.2 % in girls) and obesity (2.3 % in boys and 3.9 % in girls).

One of the approaches to study the socio-economic evolution of an area consists of an analysis of changes in income distribution. According to Gasparini & Cruces (2008), in La Plata City, as in the rest of the country, income distribution underwent

substantial changes toward greater equality from the late 1940s to the middle 1950s, and then remained relatively stable from the 1960s to 1980s, despite an increase in poverty. Starting in 1985, a hyperinflationary crisis affected the country and reached its peak in 1989. The distributive impact of this crisis resulted in a 25 % rise of poverty and a 6.3 point increase of the Gini coefficient between 1988 and 1989. In the 1990s, the Mexican crisis or “Tequila Effect” gave rise to a series of changes in employment structure, especially an increase of the participation of women in labor force, secondary workers and implementation of emergency employment programs. The Argentine economic collapse of 2001 resulted in a 17 % fall of GDP (Gross Domestic Product) per capita, with a rise of unemployment and inequality. The most dramatic phenomenon of this crisis was the combined effect of the rise in prices and the decrease of income due to the loss of economic activity. This led to an increase in poverty from 38.3 % in October, 2001 to 53 % in May, 2002. Lastly, 2003 marked the beginning of an international financial crisis that lasted until 2008 (Alvaredo 2007, Gasparini & Cruces 2008).

Thus, in the present study, the shifts occurring in soft tissues without changes in height, combined with a negative trend in muscle area, lead us to suppose that during the three-decade span analyzed, La Plata’s population has experienced deterioration in living conditions. This was observed in the characteristics of the cohorts analyzed, because in the C2 there was an increase of unemployment, informal jobs and lower levels of parents’ university level, together with a decrease in building materials quality (Cusminsky et al. 1974, Oyhenart et al. 2013). In addition, important changes in people’s lifestyles, such as an increased consumption of energy-dense foods and sedentary habits probably have taken place. The social tensions and the political instability, especially during 2001–2002, were contained by government by means of social programs intended to the members of the most vulnerable sectors, such as mothers and children. In this sense, there was a high percentage of families in C2 receiving public assistance in the form of financial support and nutritional support from the government (Oyhenart et al. 2013). Thus, public social policy reduced the level of inequality, although it did not have a significant impact on the redistribution of income throughout time. In the face of these restrictions affecting income, diet quality was more affected than total energy intake (Calvo & Aguirre 2005). In this sense, Britos (2007) reported that the caloric availability per capita in the Argentinean population increased by 40 % in recent years, with a diet characterized by a high amount of refined sugars and fats.

Even though this study was not performed in a sample representative of the entire Argentinean population, the anthropometric measurements of these two cohorts offer the advantage of including numerous children in different age groups that live in the same geographical area with those analyzed 35 years before, using the same methodology.

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## Declaration of interest

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