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Linear and ponderal growth changes in boys and girls from Puerto Madryn (Patagonia, Argentina), between 2001 and 2016

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Abstract

Background The phenotypic plasticity in growth pattern that takes place over time is described as "secular trend". The presence of secular changes evidences shifts in the environmental conditions under which a population lives. In this regard, the study of the population residing in the northeast of Argentine Patagonia is interesting because it underwent a rapid demographic growth and urban sprawl in the last 50 years.

Objective To compare height and body weight of two groups of boys and girls between 6 and 14 years old from Puerto Madryn (northeast of Argentine Patagonia) and estimate secular trend changes during the first decades of 21st century.

Sample and Methods Height and body weight of two groups of schoolchildren were compared. Data of the first group (G1) was collected in the 2001–2006 period, and of the second (G2) during 2014–2016.

To analyze the comparison between groups, the Friedman and Wilcoxon test ($p < 0.05$) were used. Centile values (3rd, 50th and 97th) of the variables by sex and age in both groups were also calculated. Then, they were compared using the Wilcoxon test.

Results Both sexes showed statistically significant differences for height in all centiles and for body weight in the 50th and 97th centiles. G2 values were above G1 for most ages.

Conclusion Boys and girls from Puerto Madryn show a positive secular trend in linear and ponderal growth patterns. These changes, registered during the first decades of the 21st century, are possibly related to the urban sprawl of the city and the variations in the associated socio-environmental and demographic conditions.

Take home message for students One of the main topics boarded in biological anthropology is the secular trend. This process, defined as phenotypic plasticity in growth pattern over time, requires an approach which allows understanding the human body as an expression place of possible conditions of inequality and inequity.

Introduction

Human growth can be conditioned by multiple factors (e.g., environmental, socio-economic, cultural, nutritional). Because of this, its study requires an integral bio-socio-cultural focus, which allows understanding the human body as an expression place of possible conditions of inequality and inequity (Nguyen and Peschard 2003). Considering this idea, plasticity is one of the main topics boarded in biological anthropology. This term was defined by Lasker (Lasker 1969) as permanent changes that occur in the individual phenotype during growth as a response to environmental non-heritable modifications. Both linear and ponderal variation over time are indicators of plasticity. The phenotypic plasticity in growth pattern that takes place over time is described as "secular trend" (Stinson 2012).

Throughout the 20th century, different factors were suggested to have a significant effect on the variation of anthropometric variables, such as access to adequate nutrition, medical care, education, money acquisition, migration and the reduction of child labour (Boas 1912; Özer and Özdemir 2020). Keeping in mind the diversity of factors which could propitiate changes in human growth, authors such as Hermanussen et al. (2010) pointed out that secular trends in different anthropometric parameters have exhibited distinctly dissimilar dynamics during the economic transition of the past 150 years. The secular trend is not a consistent and homogeneous event that occurs uniformly but can be positive (increasing size) or negative (decreasing size) (Bogin 2021a; Godina 2009; Malina 1990; Tobias 1985). The importance of assessing secular changes is that their presence evidences shifts in the environmental conditions under which a population lives and how individuals respond to those changes.

In countries such as Germany and Poland, the secular trend in the child and youth population has been studied for a long time (Gohlke and Woelfle 2009; Gomula et al. 2021; Krawczynski et al. 2003; Mumm and Hermanussen 2021; Zellner et al. 1996). In other countries with a vast territorial extension, such as Argentina, the information available about secular changes at early ages is more limited (Guimarey et al. 2014; Lomaglio et al. 1997; Orden et al. 2013). Thus, for areas such as Argentine Patagonia, little is known about this topic. However, the study of the population residing in the northeast of this particular area is interesting because it underwent rapid demographic growth and urban sprawl in the last 50 years (Kaminker 2020).

With regard to the influence of rapid urbanization on the pattern of human growth, the following hypotheses were developed:

1. During the first decades of the 21st century, variations in socio-environmental and demographic conditions related to urban sprawl recorded in Puerto Madryn (northeast of Patagonia) were conducive to secular changes in height and body weight of schoolchildren.
2. The current child and youth population from Puerto Madryn is taller and heavier than the population that resided in the city in the early 2000s.

Objective: To compare height and body weight of two groups of boys and girls between 6 and 14 years from Puerto Madryn (northeast of Argentine Patagonia) and estimate secular trend changes during the first decades of 21st century.

Sample and methods

Study area

Puerto Madryn, located in the northeast Chubut province, is the capital of the Biedma Department. It is set at 42º 46' south and 65º 02' west, 18 meters over sea level, on the southwest coast of the Golfo Nuevo, being one of the most important urban settlements of Chubut (Figure 1).
By the mid-20th century, Puerto Madryn was a railroad town, connected with the low valley of Chubut River, working as a port of incoming and outcoming sheep cattle merchandise and part of the natural resources, such as salt mines and marine fauna exploited for its fat and meat in Chubutian shores (Kaminker 2020). With the industrial promotion and the opening of the aluminum producing plant Aluar (Aluminio Argentina S.A.), in the beginning of the 1970s, the city experienced an urban sprawl and a demographic increment. This expansion was reflected in census data, showing that in just one decade the population tripled and that between 1970 and 2010, the number of inhabitants increased from 6,000 to more than 80,000. Hand in hand with this transformation, the services and infrastructure demand rose, and the urban design of the coast was modified (Bunicontro 2019). In this context, the state services did not follow a well-planned logic but a spontaneous and emergency-based one (Ferrari et al. 2019).

Study design

Two groups (G1 and G2) of schoolchildren from Puerto Madryn were compared. In both cases, measurements were taken cross-sectionally by the research team from April to November in the same 13 institutions located in different neighborhoods of the city (Figure 2).
The groups consisted of boys and girls aged 6 to 14 years. The data of the first group

Figure 1 Geographical location of the city of Puerto Madryn (Chubut, Argentina)

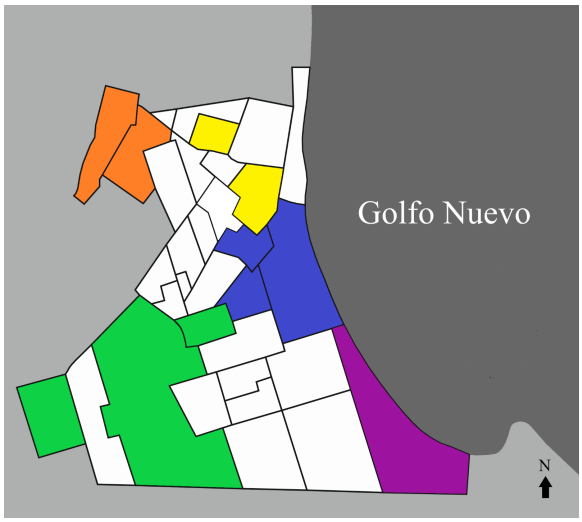

Figure 2 The neighborhoods of Puerto Madryn (Chubut, Argentina) where the study was performed. Don Bosco and Julio Roca (Northeast, yellow); Agustín Pujol I and II (Northwest, orange); Colonos Galeses, Parry Madryn and Conquistadores del Desierto (Center-east, blue); Del Desembarco (Southeast, purple); Villa Padilla, San Miguel and Gobernador Fontana (Southwest, green)

(G1) was collected in a period between 2001 and 2006, the data of the second group (G2) was obtained between 2014 and 2016 (Table 1).

The following variables were measured: i) age in years, obtained by scholar records, ii) height in centimeters, using a stadiometer (1 millimeter of precision), and iii) body weight in kilograms, using a digital portable scale (100 grams of precision). In all cases, scholars were dressed in light clothes whose weight was deducted from the total body weight. Instruments were calibrated at the beginning of each anthropometric session.

Ethical considerations

The study was endorsed and approved by the Universidad Nacional de la Patagonia San Juan Bosco, the Universidad Nacional de La Plata, and by the Comité de Bioética de la Escuela Latinoamericana de Bioética. To enter the schools, the corresponding authorization was processed at the Ministerio de Educación de la provincia de Chubut and the Subsecretaría de Educación of Puerto Madryn. The research protocols applied during the surveys were based on regulations established in the Declaration of Helsinki, dictated and upgraded by the Asociación Médica Mundial (Asociación Médica Mundial 2013). Personal data were kept according to bioethical regulations and regimentations (Ley Nacional Argentina Nº 25.326/00 and Nº 1.558/01).

Data analysis

Body height and weight were analyzed using a Friedman test ($p < 0.05$) taking two parameters into account: group (G1-G2) and sex (G1 boys versus G1 girls; G2 boys versus G2 girls). A Wilcoxon post-hoc test was applied ($p < 0.05$) to locate the statistically significant differences.

The LMS method was employed to calculate centiles for height and weight by sex and age (Cole 1990; Cole and Green 1992). The data analysis was carried out using the LMS Chartmaker Pro software (The Institute of Child Health, London, United Kingdom) (Pan and Cole 2011). The degrees of freedom (DF) values from L, M (50^{th} centile), and S, used for the adjustment to the curve, correspond to 3–5-3, respectively. For both groups, the 3^{rd}, 50^{th}, and 97^{th} centile were calculated by sex and age for comparing centile values between G1 and G2. Differences between groups at the 3^{rd}, 50^{th}, and 97^{th} centile were positive (+) when the values of G1 were higher

Table 1 Sample (group) composition by age of schoolchildren from Puerto Madryn (Argentinia)

Age (years)	Group 1 (2001–2006)		Group 2 (2014–2016)	
	♂	♀	♂	♀
6.00–6.99	194	152	130	122
7.00–7.99	213	159	145	153
8.00–8.99	197	203	146	164
9.00–9.99	184	208	140	191
10.00–10.99	142	162	125	139
11.00–11.99	175	157	146	165
12.00–12.99	168	186	166	141
13.00–13.99	182	152	126	112
Total	1455	1379	1124	1187

than G2; meanwhile the differences were negative (-) when G2 values were greater than G1. The Wilcoxon test ($p < 0.05$) was used for comparing G1 and G2.

Results

The results of the Friedman test showed significant differences (Chi squared = 9489.73; DF = 11; p = 0.000). According to the Wilcoxon post-hoc test, significant differences were found in all comparisons (Table 2).

Tables 3 and 4 show L, M, and S and selected centiles for height and weight in boys and girls as well as the results obtained by the Wilcoxon test.

In most age groups, height in G2 was significantly greater than in G1 at the 3rd, the 50th, and the 97th centile, both in boys and girls (Table 3). The same was true for body weight (Table 4).

The Figures 3 and 4 and the Tables 3 and 4 illustrate sexual dimorphism in height and weight. Greatest height differences at the 3rd centile were observed at age 11 to 13 years, greatest differences at the 50th centile at age 11, and at the 97th centile at ages 7 to 8 and 11 to 12 years. The three centiles differed most in girls.

Between the sexes, body weight differences varied the most, both at the 3rd centile and at the 50th centile, at age 11 to 12 years. Greatest weight differences between the sexes at the 97th centile were observed at the ages 7 to 8 years and at 11 and 13 years.

After analyzing average differences of body weight between G1 and G2, it was observed that the 3rd and 50th centile did not show differences among boys and girls. In the

Table 2 Comparison of height and body weight of 6–14 year old boys and girls measured between 2001–2006 (G1) and 2014–2016 (G2), Wilcoxon post-hoc test

Parameter	Variable	Z	p
Group	Height G1	-5.79	**0.000**
	Height G2		
	Body weight G1	-8.36	**0.000**
	Body weight G2		
Sex	Height ♂ G1	-3.80	**0.000**
	Height ♀ G1		
	Body weight ♂ G1	-2.57	**0.010**
	Body weight ♀ G1		
	Height ♂ G2	-3.91	**0.000**
	Height ♀ G2		
	Body weight ♂ G2	-2.30	**0.021**
	Body weight ♀ G2		

Z: Wilcoxon test
$p < 0.05$

Table 3 Height and height differences (cm) of boys and girls aged 6 to 14 years, from 2001–2006 (G1) and 2014–2016 (G2), (LMS method (Cole 1990; Cole and Green 1992))

Age (years)	3rd Centile					50th Centile					97th Centile				
	G1	G2	Dif	Z	p	G1	G2	Dif	Z	p	G1	G2	Dif	Z	p
♂															
6.0–6.9	109.3	109.4	-0.1			118.0	119.2	-1.2			127.8	128.7	-1.0		
7.0–7.9	114.0	114.3	-0.2			123.5	124.5	-1.0			134.4	135.1	-0.7		
8.0–8.9	118.7	119.1	-0.4			129.1	129.8	-0.7			141.2	141.7	-0.5		
9.0–9.9	123.2	123.8	-0.6			134.4	135.0	-0.6			147.6	148.1	-0.5		
10.0–10.9	127.8	128.3	-0.5			139.9	140.2	-0.4			154.0	154.3	-0.3		
11.0–11.9	132.8	133.0	-0.1			145.8	145.8	0.0			160.6	160.7	-0.1		
12.0–12.9	138.3	138.4	-0.1			152.1	152.3	-0.3			167.4	167.7	-0.3		
13.0–13.9	144.3	144.2	0.0			158.7	159.4	-0.7			174.4	175.0	-0.6		
Average			-0.2					-0.6					-0.5		
Wilcoxon				-2.4	0.02				-2.5	0.01				-2.5	0.01
♀															
6.0–6.9	107.4	107.2	0.2			116.8	117.7	-0.8			126.9	128.7	-1.8		
7.0–7.9	111.9	112.5	-0.6			122.0	123.4	-1.4			133.3	135.5	-2.2		
8.0–8.9	117.0	117.9	-0.9			127.8	129.2	-1.4			140.5	142.3	-1.8		
9.0–9.9	122.5	123.1	-0.6			134.1	135.0	-0.9			147.7	148.7	-1.0		
10.0–10.9	128.1	128.9	-0.8			140.5	141.2	-0.7			154.3	155.1	-0.8		
11.0–11.9	133.5	135.1	-1.5			146.6	147.6	-1.0			160.1	161.5	-1.4		
12.0–12.9	138.4	140.0	-1.6			151.9	152.5	-0.6			164.4	165.9	-1.5		
13.0–13.9	142.3	143.4	-1.1			155.7	155.5	0.2			167.2	168.3	-1.1		
Average			-0.9					-0.8					-1.4		
Wilcoxon				-2.4	0.02				-2.4	0.02				-2.5	0.01

Dif indicates the difference in centile values of G1 minus G2
Z: Wilcoxon test
< 0.05

97th centile the highest value corresponds to girls (Figure 4, Table 4).

Discussion

Between 2001 and 2016, boys and girls from Puerto Madryn showed significant positive secular changes in body height and weight, confirming our hypothesis. Similar results were shown in other Argentinian child and youth populations. A two sample comparative study, surveyed on Barrio Apolo (Catamarca province) between 1982 and 1993 by Lomaglio et al. (1997), demonstrated a positive secular trend in height in both sexes at all ages. For weight, authors registered a positive trend among boys from 9 years onwards, and in girls the positive trend was observed at all ages. As a probable cause of this variation the authors named an implementation of social policies since 1983, including improvements in child nutrition, sanitary conditions, and a greater access to health services. Orden et al. (2013) found secular changes in body height and weight among boys and girls from Santa Rosa

Table 4 Weight and weight differences (kg) of boys and girls aged 6 to 14 years, between 2001–2006 (G1) and 2014–2016 (G2), (LMS method (Cole 1990; Cole and Green 1992))

Age (years)	3rd Centile					50th Centile					97th Centile				
	G1	G2	Dif	Z	p	G1	G2	Dif	Z	p	G1	G2	Dif	Z	p
♂															
6.0–6.9	18.6	18.1	0.5			23.2	23.8	-0.6			31.7	36.3	-4.6		
7.0–7.9	20.3	20.2	0.1			26.0	27.1	-1.1			37.5	42.5	-5.0		
8.0–8.9	22.1	22.4	-0.3			29.1	30.9	-1.7			43.9	49.3	-5.4		
9.0–9.9	24.0	24.6	-0.7			32.4	34.9	-2.5			50.2	56.1	-5.9		
10.0–10.9	26.3	26.4	-0.2			36.3	38.3	-2.1			56.7	61.7	-5.0		
11.0–11.9	29.0	28.4	0.6			40.8	42.1	-1.3			63.5	67.7	-4.2		
12.0–12.9	32.2	31.4	0.8			46.0	47.4	-1.4			70.9	76.6	-5.8		
13.0–13.9	35.9	35.1	0.8			51.8	53.6	-1.7			78.8	87.4	-8.5		
Average			0.2					-1.6					-5.5		
Wilcoxon				-1.0	0.33				-2.5	0.01				-2.5	0.01
♀															
6.0–6.9	17.6	16.6	1.0			22.8	22.8	0.0			32.5	38.0	-5.4		
7.0–7.9	18.9	18.7	0.2			25.0	26.4	-1.3			37.0	44.2	-7.2		
8.0–8.9	20.8	21.0	-0.2			28.1	30.2	-2.2			42.7	50.4	-7.7		
9.0–9.9	23.3	23.3	0.0			32.1	34.2	-2.1			49.6	55.9	-6.4		
10.0–10.9	26.1	26.1	0.1			36.6	38.6	-2.0			56.3	62.0	-5.8		
11.0–11.9	29.2	29.4	-0.3			41.3	43.6	-2.4			62.2	68.8	-6.6		
12.0–12.9	32.5	32.6	-0.1			45.9	47.8	-1.9			67.2	73.7	-6.5		
13.0–13.9	35.7	35.4	0.3			50.0	50.9	-0.9			70.8	76.5	-5.7		
Average			0.1					-1.6					-6.4		
Wilcoxon				-0.4	0.67				-2.5	0.01				-2.5	0.01

Dif indicates the difference in centile values of G1 minus G2
Z: Wilcoxon test
$p < 0.05$

(La Pampa province), aged 6 and 12 years, who attended schools in 1990 and from 2005–2007. The authors observed that at 6 years old, weight increased significantly in both sexes, whereas height only increased among boys, but not girls. At the age of 12, weight had increased among both boys and girls. Height changes differed by sex: while boys did not show significant changes, girls did. A study of two groups of schoolchildren from 4 to 12 years old residing in La Plata (Buenos Aires province) in 1970 and 2005 (Guimarey et al. 2014), evidenced the presence of an increment in body weight, but there was no difference in height after the 35 years. The authors suggested that during this period, the population of La Plata had experienced deterioration in living conditions with important changes in lifestyle such as an increased consumption of energy-dense food and sedentary habits. Another example of a negative secular trend was published by Navazo et al. (2020), who found a decrease of external skeletal robustness (Frame Index = [(elbow breadth/height)×100]) in Puerto Madryn schoolchildren at the beginning of the 21st century. According to the authors, this

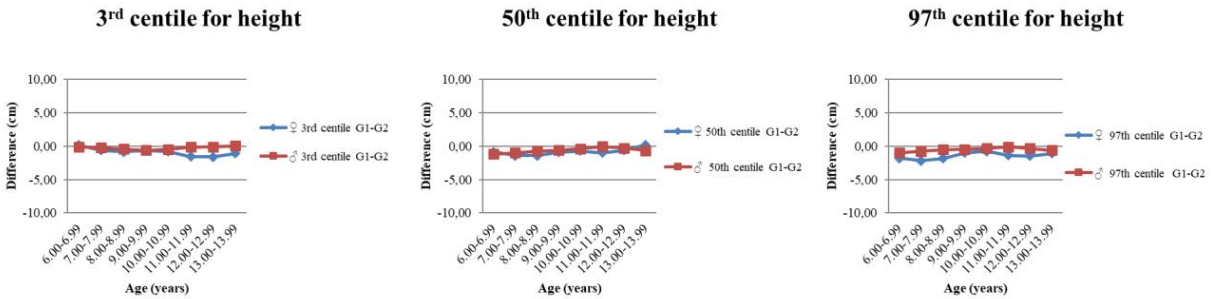

Figure 3 Difference in height (3rd, 50th, 97th centile) of boys (blue) and girls (red) aged 6 to 14 years old, between 2001–2006 (G1) and 2014–2016 (G2)

finding could be explained by changes in the quantity and/or quality of the food that children consumed and the low level of physical activity they practiced.

Other research of different trends in secular height and weight changes of Turkish primary school children within 23 years was published by Topçu et al. (2017). Whereas body weight increased in both sexes during the whole period, height of boys and girls only increased between 1993 and 2016, but not between 2003 and 2016 . The authors proposed that during the 1990s, significant improvements in environmental, economic and socio-cultural dimensions as well as health status were registered in Turkey. Yet, the secular height trends may have plateaued when the socio-economic conditions had reached a threshold. The authors suggested that children of middle socio-economic status may have eaten more in terms of food quantity but less in terms of quality.

Over the last decades, attention has not only been paid to food consumption but also to food access, affordability, and utilization. The latter are especially relevant to the majority of the world's population who now live in urban areas and primarily rely on purchasing food (Tacoli 2019). These issues are particularly important in Latin America, where rapid urbanization combined with greater access to retail food has led to particularly energy-dense and nutrient-poor diets (Corvalán et al. 2017). Zapata et al. (2016) analyzed the modifications in feeding pattern that occurred between 1996 and 2013 in Argentina. The authors found that while the intake of chicken, pork, and semi-finished meat products increased, the consumption of beef decreased. Also, wheat consumption changed as the purchase of fresh bread

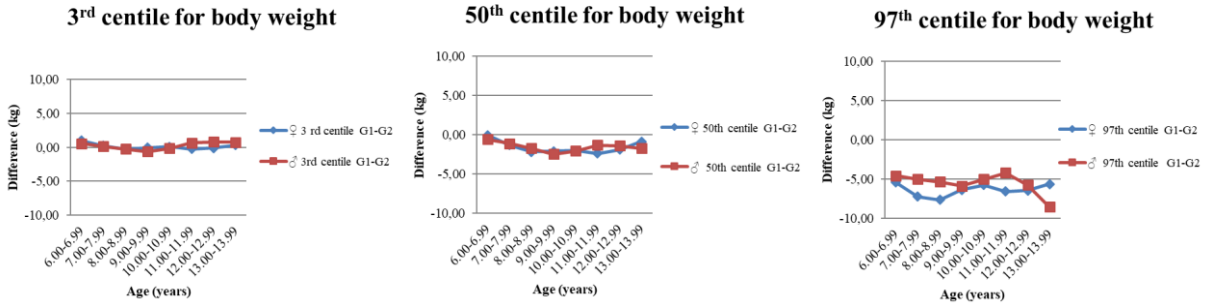

Figure 4 Differencein weight (3rd, 50th, 97th centile) of boys (blue) and girls (red) aged 6 to 14 years old, between 2001–2006 (G1) and 2014–2016 (G2)

and flour were replaced by the intake of noodles, cookies, pastry mixes and pie dough, "empanadas", and pizza (Zapata et al. 2016). Particularly in Puerto Madryn, the city supply of vegetables and meats is in charge of the Valle Inferior del Río Chubut producers(Albertoli et al. 2016). Due to the seasonality of the products and competition with other producers from the north of the country, the regional supply can vary. Therefore, many families tend to consume the cheaper, commercially processed foods (Dahinten et al. 2011).

The circumstances described above may well explain the positive secular weight trend in the schoolchildren from the northeast of Chubut. Recent considerations targeted the association between height and social parameters. Aßmann and Hermanussen proposed that people may simply be short because their friends and neighbours are short; or tall because their friends and neighbours are tall (Aßmann and Hermanussen 2013). The idea implies that schoolchildren tend to adjust in stature toward the average height of their peers. The net outcome of this regulation is that the distribution of stature of members of a community clusters toward the mean ("community effect on height") (Scheffler and Hermanussen 2018). Being short or tall may merely reflect differential effects of the community that go beyond current ideas about growth inhibition due to social stress determined by the political system, social conflict, and lack of trust among social classes. Recently, Bogin (2021b) highlighted the importance of social-economic-political-emotional (SEPE) factors for the regulation of human growth, providing a broader explanation for the plasticity in height beyond the traditional concepts focusing on nutrition, health, and genetics. The regulation of growth due to social mechanisms is not yet fully understood (Hermanussen et al. 2019).

The changes in height and weight during the last decades in Puerto Madryn were associated with rapid urbanization and a demographic expansion of the population to the west into unplanned settlements in peripheral areas. In these places, access to public services is usually poor and geomorphological processes linked to water erosion and mass removal are threatening these areas (Ferrari 2017; Ferrari and Bozzano 2016). Segura (2018) stressed that those who live in the urban periphery live far from the goods and services of modern life, but in the case of Puerto Madryn, it seems that the Neighbourhood Improvement Program (Spanish acronym: PROMEBA), supposed to consolidate informal settlements through home improvements, public service access works, the legalization of land tenure (Kaminker and Velásquez 2015), and the existence of social networks that collaborate in the containment, as well as the settlement of newly arrived families in the area (Sassone et al.) provided sufficient support to allow for positive secular trends in the growth of the schoolchildren.

Conclusions

The present study shows positive secular trends in linear and ponderal growth in boys and girls from Puerto Madryn during the first decades of the 21st century. These changes were possibly related to the urban sprawl of the city and the variations in the associated socio-environmental and demographic conditions.

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