AUTHORS:
Ana Reyes [1]
Raquel Chaves [2]
Adam Baxter-Jones [3]
Olga Vasconcelos [4]
Go Tani [5]
José Maia [4]

[1] Faculdade de Educação e Desporto, Universidade de Cabo Verde, Cabo Verde.
[2] Departamento Académico de Educação Física, Universidade Federal de Tecnologia do Paraná, Curitiba, Brasil.
[3] College of Kinesiology, University of Saskatchewan, Saskatoon, Canada.
[4] CIFI2D, Faculdade de Desporto da Universidade do Porto, Porto, Portugal.
[5] Escola de Educação Física e Esporte, Universidade de São Paulo, Brasil.

https://doi.org/10.5628/rpcd.19.03.14

Modelling the dynamics of children growth: The Vouzela study on growth, motor development and cognition.

KEYWORDS:
Child. Growth. Longitudinal. Multilevel analysis.

SUBMISSÃO: 19 de Fevereiro de 2019
ACEITAÇÃO: 5 de Novembro de 2019

ABSTRACT

The present study aimed to: (a) model children's growth in height, weight and body mass index; (b) investigate sex-differences; (c) probe the effects of socioeconomic status, weight and length at birth and weight and length gains at 18 months of age in these markers of growth; and, (d) examine children´s markers of growth trajectories within international references of WHO. Three-hundred and fourteen children of different age-cohorts were followed for three years using a mixed-longitudinal design. Height, weight, body mass index, weight and length at birth, weight and length gains at 18 months and socioeconomic status were assessed. Analyses were done in SPSS 24 and in SuperMix. Boys and girls' trajectories did not differ in height and weight. Length at birth and length gains at 18 months were associated with height. Birth weight and weight length gains at 18 months were statistically significant. Socioeconomic status and cohorts' effects were not related to any markers of growth. In conclusion, children trends in height, weight and body mass index were within normal ranges of World Health Organization Those with higher birth length and weight, and with greater length and weight gains at 18 months tended to be taller and heavier. Socioeconomic statuses and schools were not associated with their growth trajectories in height, weight and body mass index.

CORRESPONDING AUTHOR: Ana Carolina Reyes. Faculdade de Educação e Desporto (FaED), Universidade de Cabo Verde, Av. Prof. Alberto Leite, CP 263 Mindelo - São Vicente, Cabo Verde.
email: ana.rodriguez@docente.unicv.edu.cv

A modelação da dinâmica do crescimento de crianças: O estudo de Vouzela sobre crescimento, desenvolvimento motor e cognição.

RESUMO

O presente estudo teve por objetivos: (a) modelar o crescimento estatural, ponderal e índice de massa corporal de crianças; (b) descrever eventuais diferenças entre sexos; (c) pesquisar os efeitos do estatuto socioeconómico, peso e comprimento à nascença, e ganhos de peso e comprimento aos 18 meses de idade, nas velocidades de crescimento; e (d) situar as trajetórias do crescimento nas referências da Organização Mundial de Saúde. A amostra foi constituída por 314 crianças de diferentes idades seguidas consecutivamente durante três anos com recurso a um delineamento longitudinal-misto. Foi obtida informação sobre a altura, peso, índice de massa corporal, peso e comprimento à nascença, os ganhos de peso e comprimento aos 18 meses e o estatuto socioeconómico. As análises estatísticas foram realizadas nos softwares SPSS v.24.0 e SuperMix v.1. As trajetórias médias da altura e peso não diferiam entre rapazes e raparigas. O comprimento à nascença e os ganhos de comprimento aos 18 meses apenas foram significativos nas trajetórias estaturais. O peso à nascença e os ganhos de comprimento à nascença aos 18 meses foram estatisticamente significativos nos três marcadores de crescimento. Não se verificou qualquer efeito significativo do estatuto socioeconómico e das coortes. Em conclusão, as trajetórias de crescimento da altura, peso e índice de massa corporal estavam nos intervalos normais das referências da Organização Mundial de Saúde. Quanto maior for o comprimento e peso à nascença, e maiores forem os ganhos de comprimento e peso aos 18 meses tanto mais altas e pesadas eram as crianças. O estatuto socioeconómico e os contextos escolares não estavam significativamente relacionados com as trajetórias de crescimento das crianças.

PALAVRAS-CHAVE:
Criança. Crescimento.
Longitudinal. Análise multinível

INTRODUCTION

Physical growth in childhood and adolescence is marked by a plethora of systematic changes in size, shape, proportions and composition (Tanner, 1962; Roche & Sun, 2005). Further, height, weight and body mass index are probably the most important markers of children growth (World Health Organization [WHO], 1995), and these are known to be influenced by genetic factors (Thomis & Towne 2006; Visscher 2008) as well as by environmental stimuli (Ulijaszek 2006; Wells & Stock, 2011).

Growth is usually described in terms of distance and velocity curves (Kuczmarski et al., 2002; Tanner, Whitehouse, & Takaishi, 1966). Yet, children growth varies in timing and tempo that are highly visible in different segments of their body (Roche & Sun, 2005). Additionally, a broader understanding of the dynamics of children growth must also consider perinatal factors since these may have long-term consequences during their lifespan (Hack et al. 2003; Linsell et al., 2018). For example, longitudinal studies have shown that birth weight and length at birth were related to differences in children growth (Hack et al. 2003; Rogers et al. 2006; Wells, Chomtho, & Fewtrell, 2007). Further, rapid weight gains in infancy and childhood have been associated with increased risk of obesity in childhood and adulthood (Baidal et al. 2016; Karaolis-Danckert et al. 2006).

The impact of environmental factors in children growth and development are well-known (Artiningrum, Suryibroto, & Widiyani, 2014; Eveleth & Tanner, 1990; Schell, Gallo, & Ravenscroft, 2009). A recorrent theme centers around the influence of socioeconomic status (Silva et al. 2012, Silverwood, Williamson, Grundy, & De Stavola, 2016). For example, Howe et al. (2012) showed that socioeconomic differences had no impact in early infancy growth, but lightly faster growth in later childhood results in minimal widening of the height inequality. Further, Silva et al. (2012) reported that, compared to children of high socioeconomic status, those of low socioeconomic status showed an accelerated linear growth until the18th month of life, overcompensating their initial height deficit.

The school context is the most organized and structured institution also favoring children growth and development (Morgan et al. 2013). There, children spend most of their day studying, playing, doing systematic physical exercises through regular physical education classes, eating as well as learning some of the fundamentals of healthy living. This net of experiences may have some influence in children growth and development, mainly in their weight and body mass index trajectories.

Pure longitudinal study designs are necessary to better understand the independent effects of growth (Laursen, Little, & Card, 2012), however they require time and money. One way to soften these characteristics of pure longitudinal study designs is the mixed-longitudinal designs combining several cohorts, and periods of overlap, allowing for a quicker data collection (Prahl-Andersen & Kowalski, 1997).

Further, we contend that to investigate the dynamics of children growth, we should simultaneously consider important individual correlates as well as their contexts. Thus, the aims of the present paper were: (a) to describe the dynamics of children growth in height, weight and body mass index; (b) to investigate possible differences in boys and girls growth trajectories of boys and girls; (c) to explore the effects of socioeconomic status in these growth markers; (d) the influence of birth weight and length at birth and weight and length gains at 18 months of age in children growth; and (e) to examine children´s height, weight and body mass index trajectories within international references.

MATERIAL AND METHODS

SAMPLE

Data for the present study comes from the research project entitled Growth, Motor Development and Cognition Study (GMDC- Vouzela study) conducted in the Vouzela County, central region of Portugal. Children from six age-cohorts, with a two-year overlap, were recruited and were followed consecutively for three years - 2013-2014, 2014-2015, 2015-2016 (for details see Reyes et al., 2018). All were enrolled in 19 schools of Vouzela County and were invited to participate in the project; the response rate was ~90%, resulting in an overall sample of 485 children. Written informed consent was obtained from the parents and/or legal guardians and the project was approved by Vouzela educational, political and health authorities, as well as by the Ethics Committee (CEFADE 01.2016).

The current paper will only rely on 314 children from all cohorts aged four to 11 years old (165 girls, 149 boys) (TABLE 1), because we will consider those with complete data in all variables. All children with special needs were excluded from this study (*n* = 24). In addition, we tested for differences in a set of variables (sex, age, birth weight, length at birth, weight and length absolute gains from 0 to 18 months and socioeconomic status) to identify possible differences between children with complete information and those with missing data. Minor differences were found in age (0.56 yrs.), birth weight (0.11kg), and length at birth (0.60cm) favoring those included in the analysis.

TABLE 1. Cohorts, overlapping years, and total number of children per cohort.

COHORTS	AGES OF FOLLOW-UP								
Cohort 1	4	5	6						60
Cohort 2		5	6	7					59
Cohort 3			6	7	8				57
Cohort 4				7	8	9			50
Cohort 5					8	9	10		49
Cohort 6						9	10	11	39
									314

GESTATIONAL INFORMATION

All gestational information was obtained from children health booklets and confirmed by nurses from the Vouzela health-center registry. In the present study, we only consider data from birth weight (kg) and length at birth (cm), as well as weight and length absolute gains from 0 to 18 months.

ANTHROPOMETRY

Height and weight were collected following the protocols of the International Society for the Advancement of Kinanthropometry (Ross & Marfell-Jones, 1991). Height was measured using a portable stadiometer (Holtain Ltd, Crymych, United Kingdom) having children without shoes and with their head positioned in the Frankfurt plane. Weight was measured with children wearing light clothing using a TANITA portable bioelectrical impedance scale (TANITA BC-418MA Segmental Body Composition Analyzer, Tanita, Corporation, Japan). Body mass index was calculated using the usual formula: BMI = body weight (kg)/ height (m)^2.

SOCIOECONOMIC STATUS

The Portuguese school social support system, based on an index budget reference developed by the Portuguese Ministry of Education (Ministery of Social Security and Labor, 2003) for families, provides information that allowed to divide families socioeconomic status in three levels: (a) level A: up-to 2.934 €·year^{-1}, where children get books and feeding supports (lunch at school); (b) level B: from 2.934 to 5.896 €·year^{-1}, with half of level-A support; (c) level C: ≥ 5.897 €·year^{-1} implies no support.

DATA QUALITY CONTROL

The data quality control was carried out in different stages: (a) retesting a random sub--sample of children on each measurement day over the three consecutive years; (b) computing the technical error of measurement, such that it equals = 0.2 cm for height and 0.1 kg for weight; and (c) checking for data entry to identify possible punching errors and verify for the presence of outliers.

STATISTICAL ANALYSIS

Descriptive statistics (means, standard deviations and percentages) were calculated in SPSS 24.0. A multilevel modeling approach was used (Hedeker and Gibbons 2006) since data has a nested structure - repeated observations nested within subjects which are nested within schools. As advocated by Hedeker and Gibbons (2006), the time metric was centered at four years of age (time 0), such that 0, 1, 2, 3, 4, 5, 6 and 7 corresponds to 4, 5, 6, 7, 8, 9, 10 and 11 years of age. SuperMix v.1 software (Hedeker, Gibbons, du Toit, & Cheng, 2008) was used, and all model parameters were simultaneously estimated using a maximum likelihood technique. Further, models were tested sequentially: model 1 (M_1) described the best developmental trajectory for height, weight and body mass index using age, age2, sex, age-by-sex and age2-by-sex interactions as predictors as well as random components at children and school-levels; in model 2 (M_2) covariates like birth weight, and length at birth, length gain, weight gains and socioeconomic status were added as well as cohort effects given the two-year overlap of our sample design. Further, as is current in this statistical methodology (Hedeker & Gibbons, 2006), goodness of fit will be marked by the Deviance statistic. The M_1 and M_2 were compared for their better fit to the data, and the best model will show a statistically significant lower Deviance. The significant level was set at 5%.

RESULTS

Boys and girls' descriptive statistics are described in table 2. As expected, there was a clear trend for increasing height, weight and body mass index with increasing age. On average, boys had apparently higher birth weight,as well as length at birth. The same seemed to occur in weight and length gains from birth till 18 months of age. Socioeconomic status level C was the most frequent.

TABLE 2. Number of injuries registered per anatomical region, type, laterality, mechanism and potential severity.

BOYS	4 YEARS (*n* = 32)	5 YEARS (*n* = 52)	6 YEARS (*n* = 67)	7 years (*n* = 76)	8 YEARS (*n* = 80)	9 years (*n* = 75)	10 YEARS (*n*= 43)	11 years (*n* = 22)
ANTHROPOMETRY								
Height (cm)	105.3 ± 5.4	111.7 ± 5.6	119.0 ± 5.3	124.6 ± 5.7	130.9 ± 5.7	136.7 ± 5.9	142.8 ± 6.4	149.2 ± 6.1
Weight (kg)	18.8 ± 3.8	21.0 ± 3.5	24.5 ± 4.6	27.6 ± 6.2	31.8 ± 8.0	35.8 ± 8.5	39.5 ± 8.8	45.5 ± 7.5
BMI ($kg \cdot m^{-2}$)	16.8 ± 2.	16.8 ± 1.8	17.2 ± 2.3	17.6 ± 2.8	18.4 ± 3.4	19.0 ± 3.4	19.2 ± 3.5	20.4 ± 3.3
GESTATIONAL INFORMATION								
Birth weight (kg)	3.1 ± 0.4	3.0 ± 0.5	3.1 ± 0.5	3.1 ± 0.5	3.1 ± 0.4	3.2 ± 0.5	3.2 ± 0.5	3.3 ± 0.5
Length at birth (cm)	48.0 ± 1.6	47.6 ± 2.0	47.8 ± 2.1	47.6 ± 2.1	47.6 ± 2.3	47.7 ± 2.4	48.0 ± 2.7	48.5 ± 2.1
Weight at 18 months (kg)	10.9 ± 1.3	10.7 ± 1.3	10.8 ± 1.4	10.9 ± 1.2	11.0 ± 1.2	11.1 ± 1.2	11.2 ± 1.3	11.2 ± 1.1
Length at 18 months (cm)	81.7 ± 3.3	81.5 ± 3.4	80.3 ± 3.4	80.1 ± 3.3	79.7 ± 3.1	80.3 ± 3.6	80.4 ± 4.0	81.3 ± 4.5
Weight absolute gain (kg)	7.8 ± 1.9	7.8 ± 2.0	7.7 ± 1.2	7.8 ± 1.1	7.8 ± 1.2	7.9 ± 1.2	7.8 ± 1.2	7.9 ± 1.0
Length absolute gain (cm)	33.7 ± 3.1	34.0 ± 3.3	32.5 ± 3.4	32.5 ± 3.4	32.1 ± 3.4	32.6 ± 3.7	32.4 ± 4.2	32.8 ± 4.6
SOCIOECONOMIC STATUS								
A (up-to 2.934 €$\cdot year^{-1}$)	18.8%		16.4%	23.7%	22.5%	26.7%	20.9%	27.3%
B (2.934 to 5.896 €$\cdot year^{-1}$)	25.0%	19.2%	31.3%	36.8%	28.8%	26.7%	23.3%	27.3%
C (≥ 5.870 €$\cdot year^{-1}$)	56.3%	28.8%	52.2%	39.5%	48.8%	46.7%	55.8%	45.5%

GIRLS	4 YEARS (*n* = 32)	5 YEARS (*n* = 52)	6 YEARS (*n* = 67)	7 years (*n* = 76)	8 YEARS (*n* = 80)	9 years (*n* = 75)	10 YEARS (*n* = 43)	11 years (*n* = 22)
ANTHROPOMETRY								
Height (cm)	105.4 ± 3.7	113.0 ± 4.7	118.8 ± 4.8	125.4 ± 5.4	131.5 ± 6.7	137.4 ± 6.4	142.9 ± 7.5	147.3 ± 5.8
Weight (kg)	18.2 ± 2.3	21.8 ± 3.2	23.8 ± 3.7	27.2 ± 4.7	30.4 ± 6.9	34.5 ± 7.4	38.3 ± 9.7	42.5 ± 7.1
BMI ($kg \cdot m^{-2}$)	16.3 ± 1.4	17.0 ± 2.0	16.9 ± 2.2	17.2 ± 2.4	17.4 ± 2.9	18.1 ± 2.9	18.6 ± 3.4	19.5 ± 2.6
GESTATIONAL INFORMATION								
Birth weight (kg)	3.1 ± 0.6	3.3 ± 0.7	3.3 ± 0.6	3.4 ± 0.5	3.2 ± 0.6	3.2 ± 0.6	3.1 ± 0.6	3.2 ± 0.3
Length at birth (cm)	48.4 ± 2.7	48.7 ± 2.5	48.6 ± 2.4	48.6 ± 2.2	47.9 ± 2.9	48.1 ± 2.9	47.9 ± 3.2	48.6± 1.8
Weight at 18 months (kg)	11.2 ± 1.5	11.6 ± 1.4	11.6 ± 1.2	11.7 ± 1.1	11.6 ± 1.2	11.7 ± 1.3	11.7 ± 1.4	11.9 ± 1.0
Length at 18 months (cm)	80.9 ± 2.7	82.2 ± 3.3	82.1 ± 3.5	82.4 ± 3.4	82.2 ± 3.5	81.8 ± 3.3	81.9 ± 3.4	81.4 ± 3.8
Weight absolute gain (kg)	8.1 ± 1.2	8.3 ± 1.1	8.3 ± 1.1	8.3 ± 1.1	8.4 ± 1.2	8.4 ± 1.3	8.6 ± 1.3	8.7 ± 1.1
Length absolute gain (cm)	32.6 ± 2.7	33.4 ± 3.0	33.5 ± 3.5	33.8 ± 3.5	34.2 ± 3.8	33.7 ± 3.6	34.0 ± 3.8	32.8 ± 3.7
SOCIOECONOMIC STATUS								
A (up-to 2.934 €$\cdot year^{-1}$)	25.0%	19.6%	13.2%	15.4%	13.4%	15.3%	7.5%	7.1%
B (2.934 to 5.896 €$\cdot year^{-1}$)	17.9%	17.9%	23.5%	20.0%	23.9%	27.1%	37.5%	57.1%
C (≥ 5.870 €$\cdot year^{-1}$)	57.1%	62.5%	63.2%	64.6%	62.7%	57.6%	55.%	35.7%

Growth trends in height, weight and body mass index, as well as their interactions with sex, show specificities which are unique to each (TABLE 3). In height, there is apparently no trend for acceleration (β = 0.007 ± 0.02, p = .78), although there is a significant effect of the interaction with sex (β = -0.07 0.03, p = .03). Yet, at four years of age, boys and girls do not differ in their mean heights (β = 1.10 ± 0.09, p = .09). In weight, there is evidence of a curvilinear trend (β = 0.23 ± 0.03, p < .001), as well as an interaction with sex (β = -0.08 ± 0.04, p = .04). As with height, boys and girls show no mean differences in their weight at four years of age (β = 0.01 ± 0.56, p = .90). Body mass index shows a clear curvilinear trend (β = 0.05 ± 0.02, p = .003), with no differences in developmental trajectories of boys and girls. School random effects do not differ (p > 0.05) in any of the growth markers, and because of this will be removed in the next model. Further, significant children heterogeneity in height, weight and body mass index at four years of age were noticed (height σ^2 = 18.03 ± 2.10, p < .001; weight σ^2 = 8.47 ± 1.31, p < .001, body mass index σ^2 = 3.95 ± 0.54, p < .001) as well as in their developmental trajectories (height σ^2 = 0.33 ± 0.10, p = .001, weight σ^2 = 1.62 ± 0.21, p < .001, body mass index σ^2 = 0.21 ± 0.04, p < .001).

TABLE 3. Parameter estimates (standard-errors) for fixed and random effects for height, weight and body mass index (Model 1).

	HEIGHT	WEIGHT	BMI
REGRESSION COEFFICIENTS (FIXED EFFECTS)			
Intercept (4 years)	105.62 (0.61)***	18.78 (0.44)***	16.75 (0.25)***
Age (velocity)	6.33 (0.18)***	2.21 (0.22)***	0.15 (0.12)ns
Age^2 (acceleration)	0.007 (0.02)ns	0.23 (0.03) ***	0.05 (0.02)**
Sex (boys)	1.10 (0.09)ns	1.01 (0.56)ns	-0.18 (0.35)ns
Age-by-sex	0.13 (0.26)ns	0.13 (0.31)ns	-0.05 (0.17)ns
Age^2-by-sex	-0.07 (0.03)*	-0.08 (0.04)*	-0.01 (0.02)ns
VARIANCE COMPONENTS (RANDOM EFFECTS)			
School Level			
Intercept	2.49 (0.09)NS	0.60 (0.52)NS	-0.01 (0.08)NS
Child Level			
Intercept	18.03 (2.10)***	8.47 (1.31)***	3.95 (0.54)***
Age	0.33 (0.10)**	1.62 (0.21)***	0.21 (0.04)***
Covariance (intercept/age)	1.0 (0.36)**	0.68 (0.42)NS	-0.002 (0.13)NS
Residual Level			
Intercept	1.42 (0.11)***	1.57 (0.17)***	0.54 (0.04)***
MODEL SUMMARY			
Deviance	3996.15	4114.47	3049.51
Number of estimated parameters	11	11	11

BMI = body mass index; CE = cohort effects; CE_c2_1 is the overlapping effect of cohort 2on cohort 1; SES = socioeconomic status; ns = non--statistically significant; * p < .05; ** p < .01; *** p < .001.

Model 2 results are in table 4.

TABLE 4. Parameter estimates (standard-errors) for fixed and random effects for height, weight and body mass index (Model 2).

	HEIGHT	WEIGHT	BMI
REGRESSION COEFFICIENTS (FIXED EFFECTS)			
Intercept (4 years)	105.60 (0.67)***	19.11 (0.62)***	17.05 (0.34)***
Age (velocity)	6.37 (0.19)***	2.12 (0.25)***	0.10 (0.12)ns
Age^2 (acceleration)	0.004 (0.03)ns	0.24 (0.03)***	0.05 (0.02)**
Sex (boys)	-0.23 (0.61)ns	-1.22 (0.50)*	-0.81 (0.31)**
Age-by-sex	0.04 (0.26)ns	0.06 (0.30)ns	-0.02 (0.16)ns
Age^2-by-sex	-0.06 (0.04)ns	-0.07 (0.04)ns	-0.01 (0.02)ns
CE_C2_1	0.46 (0.52)NS	0.07 (0.46)NS	-0.11 (0.25)NS
CE_C3_2	0.56 (0.72)NS	-0.29 (0.72)NS	-0.33 (0.36)NS
CE_C4_3	0.12 (0.82)NS	0.11 (0.88)NS	0.02 (0.42)NS
CE_C5_4	-0.57 (0.83)NS	0.23 (0.91)NS	0.12 (0.43)NS
CE_C6_5	-1.39 (0.72)NS	-1.19 (0.79)NS	0.29 (0.38)NS
Birth weight (kg)		2.02 (0.35)***	1.67 (0.31)***
Weight absolute gain (kg)		1.63 (0.16)***	1.04 (0.11)***
Length at birth (cm)	1.04 (0.11)***		-0.26 (0.08)***
Length absolute gain (cm)	0.79 (0.08)***		-0.13 (0.08)**
SES (level B)	0.65 (0.73)NS	0.63 (0.56)NS	0.14 (0.34)NS
SES (Level C)	0.11 (0.65)NS	0.54 (0.49)NS	0.14 (0.30)NS
VARIANCE COMPONENTS (RANDOM EFFECTS)			
Child Level			
Intercept	13.96 (1.70)***	4.80 (0.91)***	2.26 (0.38)***
Age	0.38 (0.10)***	1.50 (0.20)***	0.17 (0.04)***
Covariance (intercept/age)	0.22 (0.34)ns	0.22 (0.36)ns	0.07 (0.11)ns
Residual Level			
Intercept	1.37 (0.11)***	1.65 (0.13)***	0.58 (0.04)***
MODEL SUMMARY			
Deviance	3884.13	4002.69	2950.36
Number of estimated parameters	19	19	21

BMI = body mass index; CE = cohort effects; CE_c2_1 is the overlapping effect of cohort 2 on cohort 1; SES = socioeconomic status; ns = non--statistically significant;* p < .05; ** p < .01; *** p < .001

Figure 1 contrasts mean heights, weights and body mass index of Vouzela children with the international reference centile charts (Kuczmarski et al. 2002). In general, boys and girls mean heights are at 75th percentile. Weight and body mass index, in boys and girls, were between the 75th and the 90th percentiles.

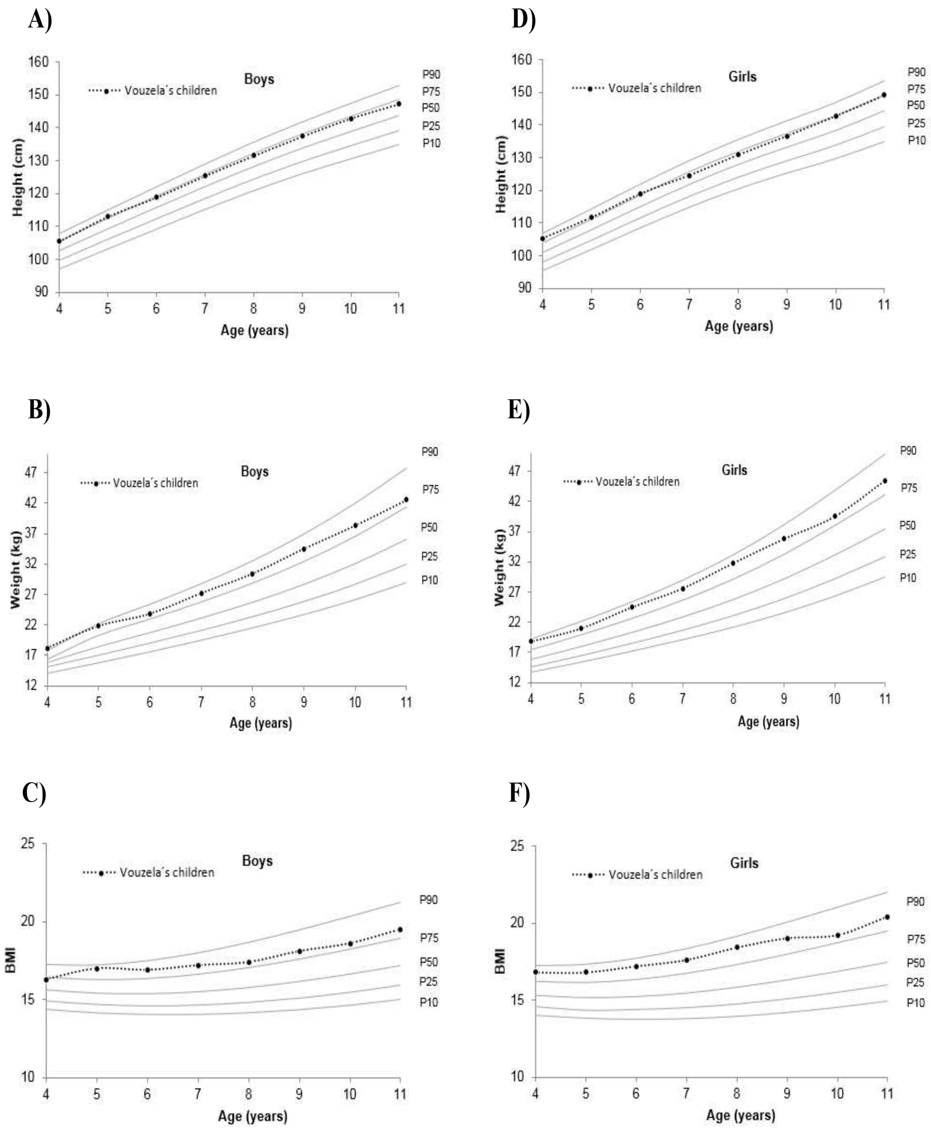

FIGURE 1. Plotting of Vouzela children height, weight and body mass index within Centers of Disease Control and Prevention reference charts.

DISCUSSION

This study investigated children growth longitudinal trajectories in height, weight and body mass index. Sex-differences, as well as the effects of socioeconomic status, birth weight and length at birth and weight, and at 18 months of age in these markers of growth were also analyzed. In model 1, we reported that primary school-children changes in height, weight and body mass index exhibited a curvilinear trajectory. These results are apparently similar to other non-statistically modelled longitudinal accounts expressed in centile charts for this period of age (Kuczmarski et al., 2002; Tanner et al., 1966).

At four years old, no sex-differences were noticed in height, weight and body mass index. However, there is a systematic tendency for girls to surpass boys in their height and weight trends. These differences are well-know, and they are most probably related to earlier mid-growth spurt of girls and their adolescent spurt (Gasser et al. 1985). They are also related to hormonal influences (i.e., estrogen), which begins to function earlier in girls, preparing them for menarche (Riggs, Khosla, Melton III, 2002; Wells, 2007).

Vouzela schools seemingly do not explain any amount of significant variation in children height, weight and body mass index trajectories. This may be mostly due to the fact that there is not much variation across schools in their nutritional habits, healthy conditions, physical and built environments. Of the 19 schools in Vouzela, 15 (□80%) have a group that supervises or gives guidance (for example, a health team and/or school action) on those practices and policies. All schools have qualified physical education teachers and have similar materials for their classes.

In model 2, we added predictors (cohort effects, socioeconomic status, length at birth and length gain at 18 months in height; birth weight and weight gain at 18 months) in all three growth markers and a little different growth developmental narrative appeared the best developmental trajectory for growth. Trend in height it is now linear and there is no more significant interaction of age2-by-sex in height and weight. Boys were lighter than girls at 4 years and had lower body mass index values.

Given the mixed-longitudinal nature of the design, cohort effects were modelled and tested, as advocated by Prahl-Andersen and Kowalski (1973), because it is possible that histories and children growth and developmental histories within each age-cohort, may have differently impacted their growth trends. However, not statistically significant impact was identified for these effects.

We also did not find any relationship between children socioeconomic status and their growth trajectories, and existing information of this association is inconsistent. For example, Howe et al. (2012), using data from the ALSPAC study, examined 12366 English children growth conditional on their socioeconomic pattering. Socioeconomic differences in childhood growth were small and only resulted in minimal widening of the height variation with increasing age. Also, socioeconomic differences in weight during childhood are strongly marked by inequalities in length at birth, with small increases in such inequalities in growth occurring later in childhood.

Yet, Silva et al. (2012), using data from the Generation R Study, from 2972 Dutch mothers and their children, studied maternal education level as a measure of socioeconomic status and its association with repeatedly measured at 2, 6, 14 and 25 months of age. They found that at two months, children in the lowest education subgroup were shorter than those in the highest. Between one and 18 months, they grew faster than their counterparts. By 14 months, children in the lowest educational subgroup were taller than those in the highest. In conclusion, compared with children of high socioeconomic status, those of low show an accelerated linear growth until 18th month of life, leading to an overcompensation of their initial height deficit. Vouzela's characteristics, as the predominance of a rural and a semi-urban city, maybe are responsible for not finding differences in the socioeconomic status effect, even if there is socioeconomic status inequality, the action of the public power can reach all social strata.

Length at birth and length gain at 18 months were positively related with children height trajectories, and the same occurred to birth weight and weight gains. Jointly, birth weight and weight gains were also positively related to children body mass index trajectories and length at birth and length gain were negatively associated. These results are aligned with previous research. For example, Rogers et al. (2006) investigated the potential associations between weight and length at birth with subsequent lean and total body fat in 6086 (3080 girls) children aged 9-10-y-old. The results showed that higher ponderal index at birth (weight/length3) was related with both higher fat and lean mass in childhood but also with an increase in the fat-to-lean mass ratio. Also, Wells, Hallal, Wright, Singhal, and Victora (2005) tested if prenatal growth (birth weight or ponderal index) and postnatal weight gains (during infancy and childhood) were associated with body composition in later childhood in 172 Brazilian boys. As a result, birth weight was correlated with later height and lean mass, but not fatness; weight gain 0-6 months was correlated with later height, lean mass and body mass index, but not with fatness. Also, weight gain 1-4 yrs. was associated with later fatness and lean mass. The Vouzela health center has great concern and caution regarding pregnant women and their newborns. The majority of them had more than five consultations during pregnancy, thus following the growth of the baby and future problems. For example, of all the children evaluated in this study and with gestational information, only 35 had low birth weight.

The last purpose of the present study was to examine children height, weight and body mass index trajectories within international references. Children weight and body mass index mean values were located between the 75th and the 90th percentiles of the international growth references by age and sex (Kuczmarski et al., 2002). This is important information for parents, educators and Vouzela authorities since childhood overweight and obesity has systematically grown during the last decades and are global challenges (Lindholm et al., 2018) with adverse consequences for their current health (Lakshman, Elks, & Ong, 2012; Llewellyn, Simmonds, Owen, & Woolacott, 2016).

This study is not without limitations. First, our sample is not representative of the whole country and care must be taken with generalization of the results. Second, we do not have data about children´s nutritional habits which could be linked to their weight gains. Third, the number of schools is reduced and this may have caused its variance to be non-significant. However, this study also has strengths. First, the sample included children aged four to 11 years old which is considered an important development time window during their physical growth. Second, the inclusion of important predictors allowed or a more encompassing way to understand children growth. Third, the use of the mixed model and its many capabilities in terms of modeling children growth as well as the associations with different covariates adjusted for age-cohort effects.

CONCLUSIONS

Vouzela children trends in height, weight and body mass index were within ranges of international normative values. Further, those with higher birth length and weight, with greater length and weight gains at 18 months tended to be taller, heavier and with greater body mass index. Children socioeconomic statuses were not associated with their growth trajectories in height, weight and body mass index. Schools did not have any exploratory power in Vouzela children differences in their weight and body mass index changes across time.

ACKNOWLEDGMENTS

We thank the Vouzela City Hall, School authorities, Health Center nurses, psychologists, school teachers, children and parents for their support in participating in the study across the three years.

REFERENCES

Artiningrum, N. T., Suryibroto, B., & Widiyani, T. (2014). Physical growth of Sasak children at different altitudes in Lombok Island. *HAYATI Journal of Biosciences, 21*(3), 101-110. doi:10.4308/hjb.21.3.101

Baidal, J. A. W., Locks, L. M., Cheng, E. R., Blake-Lamb, T. L., Perkins, M. E., & Taveras, E. M. (2016). Risk factors for childhood obesity in the first 1,000 days: A systematic review. *American Journal of Preventive Medicine, 50*(6), 761-779. doi:10.1016/j.amepre.2015.11.012

Eveleth, P. B., & Tanner, J. M. (1990). *Worldwide variation in human growth*. Cambridge, UK: Cambridge University Press.

Gasser, T., Müller, H. G., Köhler, W., Prader, A., Largo R., & Molinari, L. (1985). An analysis of the mid-growth and adolescent spurts of height based on acceleration. *Annals of Human Biology, 12*(2), 129-148. doi:10.1080/03014468500007631.

Hack, M., Schluchter, M., Cartar, L., Rahman, M., Cuttler, L. & Borawski, E. (2003). Growth of very low birth weight infants to age 20 years. *Pediatrics, 112*(1), 30-38. doi:10.1542/peds.112.1.e30

Hedeker, D., & Gibbons, R. (2006). *Longitudinal data analysis*. New York, NY, USA: Wiley.

Hedeker, D., Gibbons, R., du Toit, M. & Cheng, Y. (2008). *Supermix: Mixed effects models*. Lincolnwood, IL, USA: Scientific Software International.

Howe, L. D., Tilling, K., Galobardes, B., Smith, G. D., Gunnell, D., & Lawlor, D. A. (2012). Socioeconomic differences in childhood growth trajectories: At what age do height inequalities emerge? *Journal of Epidemiology and Community Health, 66*(2), 143-148. doi:10.1136/jech.2010.113068

Karaolis-Danckert, N., Buyken, A. E., Bolzenius, K., Perim de Faria, C., Lentze, M. J., & Kroke, A. (2006). Rapid growth among term children whose birth weight was appropriate for gestational age has a longer lasting effect on body fat percentage than on body mass index. *The American Journal of Clinical Nutrition, 84*(6), 1449-1455. doi:10.1093/ajcn/84.6.1449

Kuczmarski, R. J., Ogden, C. L., Guo, S. S., Grummer-Strawn, L. M., Flegal, K. M., Mei, Z., ... & Johnson, C. L. (2002). 2000 CDC growth charts for the United States: Methods and development. *Vital Health Stat, 11*(246), 1-190.

Lakshman, R., Elks, C. E., & Ong, K. K. (2012). *Childhood obesity. Circulation, 126*(14), 1770-1779.

Laursen, B., Little, T. D., & Card, N. A. (Eds.). (2012). *Handbook of developmental research methods*. New York, NY, USA: The Guilford Press.

Lindholm, A., Bergman, S., Alm, B., Almquist-Tangen, G., Dahlgren, J., & Roswall, J. (2019). Infant body mass index growth patterns predicted overweight at five years, waist-to-height ratio did not add to this predictivity. *Acta Paediatrica, 108*(5), 945-953.

Linsell, L., Johnson, S., Wolke, D., Morris, J., Kurinczuk, J. J., & Marlow, N. (2019). Trajectories of behavior, attention, social and emotional problems from childhood to early adulthood following extremely preterm birth: a prospective cohort study. *European Child & Adolescent Psychiatry, 28*(4), 531-542.

Llewellyn, A., Simmonds, M., Owen, C. G., & Woolacott, N. (2016). Childhood obesity as a predictor of morbidity in adulthood: A systematic review and meta-analysis. *Obesity Reviews, 17*(1), 56-67.

Ministery of Social Security and Labor. (2003). *Decreto-Lei, n.o 176/2003 de 2 de Agosto*. I. S.-. A. Portugal, Diário da República.

Morgan, P. J., Barnett, L. M., Cliff, D. P., Okely, A. D., Scott, H. A., Cohen, K. E., & Lubans, D. R. (2013). Fundamental movement skill interventions in youth: A systematic review and meta-analysis. *Pediatrics, 132*(5), e1361-e1383.

Prahl-Andersen, B., & Kowalski, C. J. (1973). A mixed longitudinal, interdisciplinary study of the growth and development of Dutch children. *Growth, 37*(3), 281-295.

Reyes, A. C., Chaves, R., Baxter-Jones, A. D., Vasconcelos, O., Tani, G., & Maia, J. (2018). A mixed-longitudinal study of children's growth, motor development and cognition: Design, methods and baseline results on sex-differences. *Annals of Human Biology, 45*(5), 376-385.

Riggs, B. L., Khosla, S., & Melton III, L. J. (2002). Sex steroids and the construction and conservation of the adult skeleton. *Endocrine Reviews, 23*(3), 279-302.

Roche, A. F., & Sun, S. S. (2005). *Human growth: Assessment and interpretation*. Cambridge, UK: Cambridge University Press.

Rogers, I. S., Ness, A. R., Steer, C. D., Wells, J. C., Emmett, P. M., Reilly, J. R., ... & Smith, G. D. (2006). Associations of size at birth and dual-energy X-ray absorptiometry measures of lean and fat mass at 9 to 10 y of age. *The American Journal of Clinical Nutrition, 84*(4), 739-747.

Ross, W. D., & Marfell-Jones, M. J. (1991). *Kinanthropometry: Physiological testing of elite athlete*. London, UK: Human Kinetics.

Schell, L. M., Gallo, M. V., & Ravenscroft, J. (2009). Environmental influences on human growth and development: Historical review and case study of contemporary influences. *Annals of Human Biology, 36*(5), 459-477.

Silva, L. M., van Rossem, L., Jansen, P. W., Hokken-Koelega, A. C., Moll, H. A., Hofman, A., ... & Raat, H. (2012). Children of low socioeconomic status show accelerated linear growth in early childhood: Results from the Generation R Study. *PloS one, 7*(5), e37356. doi:10.1371/journal.pone.0037356

Silverwood, R. J., Williamson, L., Grundy, E. M., & De Stavola, B. L. (2016). Pathways between socioeconomic disadvantage and childhood growth in the Scottish Longitudinal Study, 1991-2001. *PloS one, 11*(10), e0164853. doi:10.1371/journal.pone.0164853

Tanner, J. M. (1962). *Growth at adolescence* (2nd ed.). Oxford, UK: Blackwell Scientific Publications.

Tanner, J. M., Whitehouse, R., & Takaishi, M. (1966). Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, part 2. *Archives of Disease in Childhood, 41*, 613-635.

Thomis, M. A., & Towne, B. (2006). Genetic determinants of prepubertal and pubertal growth and development. *Food and Nutrition Bulletin, 27*(4), 257-278.

Ulijaszek, S. J. (2006). The international growth standard for children and adolescents project: Environmental influences on preadolescent and adolescent growth in weight and height. *Food and Nutrition Bulletin, 27*(4), 279-294.

Visscher, P. M. (2008). Sizing up human height variation. *Nature Genetics, 40*(5), 489-490.

Wells, J. C. (2007). Sexual dimorphism of body composition. *Best Practice & Research Clinical Endocrinology & Metabolism, 21*(3), 415-430.

Wells, J. C., Chomtho, S., & Fewtrell, M. S. (2007). Programming of body composition by early growth and nutrition. *Proceedings of the Nutrition Society, 66*(3), 423-434.

Wells, J. C., Hallal, P. C., Wright, A., Singhal, A., & Victora, C. G. (2005). Fetal, infant and childhood growth: Relationships with body composition in Brazilian boys aged 9 years. *International Journal of Obesity, 29*(10), 1192-1198.

Wells, J. C., & Stock, J. T. (2011). Re-examining heritability: Genetics, life history and plasticity. *Trends in Endocrinology & Metabolism, 22*(10), 421-428.

World Health Organization. (1995). Physical status: The use of and interpretation of anthropometry. *WHO Technical Report Series, 854*(9).