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Longitudinal changes in adiposity during adolescence: a population-based cohort

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ABSTRACT

Objective: We aimed to assess the trends in body mass index (BMI) and body fat percentage (BF%) from the age of 13 to 17 years and to evaluate how sociodemographic and behavioural characteristics at the age of 13 impact changes in BMI and BF%.

Setting: Porto, Portugal.

Participants: We evaluated 1451 adolescents in a community-based cohort.

Outcome measures: BMI z-scores were calculated according to CDC references. BF% was assessed by bioelectrical impedance. Variables with a significant effect in adiposity changes were identified through linear regression models. In girls, estimates were controlled for duration of follow-up, parental education, baseline BMI z-score, age at menarche and the interaction term baseline BMI z-score×age at menarche; in boys, adjustments were performed for duration of follow-up, parental education, baseline BMI z-score and the interaction term baseline BMI z-score×duration of follow-up.

Results: On average, BMI z-score decreased from the age of 13 to 17 years (mean difference −0.20, 95% CI −0.23 to −0.16 among girls and −0.15, 95% CI −0.19 to −0.11 among boys). Accordingly, 12.4% of girls and 13% of boys moved to a lower BMI category and 2.2% of girls and 5.5% of boys to a higher category. There were sex differences in the significant determinants of adiposity trends. Among girls, BMI z-score significantly decreased with baseline BMI z-score (β=−0.163, 95% CI −0.204 to −0.122) and significantly increased with age at menarche (β=0.078, 95% CI 0.050 to 0.107). Results were similar for BF%. Among boys, BMI z-score significantly increased with higher parental BMI, and BF% decreased among those who wished to look larger at the age of 13 (β=−1.367, 95% CI −2.174 to −0.560), compared with those who were satisfied with their image.

Conclusions: In adolescents, ageing resulted in a decrease in BMI z-scores and BF%. BMI and BF% at the age of 13 were the major determinants of the observed trends. Our results suggest that adolescence is a possible specific time window for intervention.

Strengths and limitations of this study

- A population-based study conducted on a large representative sample of adolescents, with a high proportion of participation.
- A prospective study using data from two evaluations of the Epidemiological Health Investigation of Teenagers in Porto (EPITeen) cohort, between the age of 13 and 17 years.
- Evaluation of adiposity through two different measures: body mass index and body fat percentage.
- Participants' exclusion due to missing data.

INTRODUCTION

During the past three decades most countries have recorded an increase in childhood overweight and obesity.[1] This trend might finally result in higher mortality and morbidity in the short term and the long term, reversing the general improvement in life expectancy observed during the past decades.[2–5]

Specific periods of human growth, such as adolescence, are critical for the development of obesity.[6] Early puberty is associated with overweight or fatness in young adulthood[7 8] and obesity occurring at this age seems even more likely to persist than childhood obesity.[9]

There is extensive international information on point prevalence and time trends in the prevalence of overweight and obesity in children and adolescents.[10 11] However, few data[10–13] are available describing the incidence of obesity or quantitative longitudinal changes in body mass index (BMI) during adolescence. Despite being a relatively short period, adolescence is associated with intense changes in the biological, psychological and social characteristics, resulting in increased individual autonomy. Adolescents progressively gain more control over what, when and where they eat[14 15] and also become more susceptible to social and peer pressures, particularly concerning weight and ideal body shape[16 17] that might result in the adoption of strategies to control weight.

The study of how BMI evolves during adolescence provides additional information to understand the determinants of obesity during the life course. Additionally, since changes in body composition might influence the risk of disease later in life,[4 18 19] it is important to identify these changes, beyond those measured through BMI.[20 21]

The present study describes the changes in BMI and in body fat percentage (BF%) between the age of 13 and 17 years, and explores the role of sociodemographic and behavioural characteristics at the age of 13 on such changes.

METHODS

Eligible participants were urban adolescents, members of the Epidemiological Health Investigation of Teenagers in Porto (EPITeen) cohort. As previously reported,[22] in 2003/2004 we assembled a cohort of adolescents born in 1990 and enrolled at public and private schools in Porto, Portugal. The second evaluation of this cohort took place in the 2007/2008 school year.

Participants

At baseline, 2160 adolescents agreed to participate and provided information at least for part of the planned assessment, resulting in a 77.5% participation proportion. Four years later, 1716 (79.4%) participants were re-evaluated.

For analysis we excluded those participants who had missing values for weight or height (n=95) or for BF% (n=10) and 160 participants who had missing values for parental education, parental BMI or age at menarche. Thus, this analysis was based on 1451 participants.

Compared with the 1451 participants considered in the analysis, participants not included (not re-evaluated or with missing values) significantly more often belonged to public schools (83.2% vs 73.1%, p<0.001) and to families with less educated parents (parental education <6 years: 40.8% vs 21.8%). No significant differences were found regarding sex, baseline adolescent and parental BMI categories.

Data collection

Both evaluations followed the same procedures and used self-administered and standardised questionnaires. Additionally, a physical examination was performed in school by a trained team.

We included in our analysis the variables that in previous analyses were seen to be associated with obesity in our sample.[22]

The weight and height of the participants were obtained in light indoor clothes and no shoes. Weight was measured in kilograms to the nearest 10th, using a digital scale and height was measured in centimetres to the nearest 10th, using a portable stadiometer.[22] Age-specific and sex-specific BMI z-scores were computed based on the United States Centers for Disease Control and Prevention Growth Charts.[23] Additionally, adolescents were classified as overweight if their BMI was at or above the 85th centile and below the 95th centile and as obese if their BMI was at or above the 95th centile. In order to characterise changes in BMI between the two evaluations, we also created a new variable with four categories: (1) normal at both (BMI <85th centile at both moments); (2) overweight/obese at both (overweight at both moments, or obese at both moments); (3) increasing (changed to a higher BMI category); and (4) decreasing (changed to a lower BMI category).

BF% was estimated by foot-to-foot bioelectrical impedance (Tanita TBF-300, Tanita Corporation of America, Inc, Illinois, USA).

The weight and height of the parents were self-reported and their BMI was categorised according to the WHO classification.[24] We built a variable named parental BMI that considered the higher category of BMI regardless of being from the mother or the father. We tested different models using the variables mother's BMI and father's BMI separately, and the results were similar to those using the combined variable parental BMI. Additionally, as parental BMI allowed the minimisation of missing data, we decided to use this combined variable.

Parental education level was measured as the number of successfully completed years of formal schooling and we considered the information from the parent with the higher educational level.

Adolescents were asked to report separately the time on weekends spent watching television, reading, doing homework, playing computer or video games. Regular practice of sports corresponds to the frequency of spending at least 20 consecutive minutes in sport activities, beyond compulsory school activities. Additionally, we evaluated self-perception of leisure-time activities according to four subjective intensity categories (mainly sitting, mainly standing, active or very active).

Perceived and desired body images were determined using a body shape representation from the Stunkard Figure Rating Scale.[25] Participants were provided with a set of two scales depicting either the male or the female form and they were required to choose what their perceived figure was and what their desired figure was. Body dissatisfaction was defined as a discrepancy between the perceived and the desired figures (perceived figure rating minus desired figure rating), as previously described.[26] Thus, a positive rating indicates that participants report a desired figure thinner than the perceived, whereas a negative rating indicates that participants report a desired figure larger than the perceived.

The time period between follow-up and baseline examinations was computed for each adolescent to the nearest month.

Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), V.17.0.

Quantitative variables were compared using the Mann-Whitney test and the χ^2 test was used to compare proportions. The normality distribution of quantitative variables was checked using the Shapiro-Wilk test.

Regression coefficients (β) and 95% CIs were used to estimate the association between sociodemographic and behavioural variables at baseline (independent variables) and the change in BMI z-score and in BF% (follow-up *minus* baseline). Results were stratified by sex and estimates were adjusted for potential confounders: in girls, estimates were controlled for duration of follow-up, parental education, baseline BMI z-score, age at menarche and an interaction term (baseline BMI z-score×age at menarche); in boys, adjustments were performed for duration of follow-up, parental education, baseline BMI z-score and an interaction term (baseline BMI z-score×duration of follow-up).

Similar models were computed for change in the BF% between follow-up and baseline, with analogous adjustments using BF% instead of BMI z-score.

Since the models included interaction terms, we centred at the mean the variables BF%, age at menarche and duration of follow-up for which zero value has no meaning.

Ethical considerations

Procedures were developed to guarantee data confidentiality and protection. Parents and adolescents received written and oral information explaining the purpose and design of the study and written informed consent was obtained from both.

RESULTS

The mean (SD) time of follow-up was 38.3 (5.2) months. In this period, using the CDC Growth Charts (USA) as reference, BMI z-score showed a mean (95% CI) decrease of −0.20 (−0.23 to −0.16) among girls and −0.15 (−0.19 to −0.11) among boys (p=0.089). During the same period BF% also decreased, the mean (95% CI) change was −1.33 (−1.71 to −0.94) in girls and −1.46 (−1.85 to −1.07) in boys (p=0.632).

Distribution of BMI categories at the age of 17, according to BMI categories at the age of 13 is presented in figure 1. Additionally, we present in table 1 the characterisation of these changes using a variable that summarises the changes in BMI categories. The majority of adolescents remained of normal weight (BMI <85th centile) between the age of 13 and 17 years and about 10% (8.9% in girls and 11.7% in boys) remained overweight or obese. On the other hand, 12.4% of girls and 13% of boys moved to a lower BMI category, while 2.2% and 5.5%, respectively, changed their status to a higher category of BMI.

In order to evaluate the global changes in BMI, including those that occurred within the same BMI category, we analysed the association of participants' characteristics with changes in BMI z-score using the variable as continuous, and also with changes in BF%. Among female adolescents (table 2), after adjustment, BMI z-score (β=−0.008, 95% CI −0.014 to −0.002) and BF% (β=−0.221, 95% CI −0.282 to −0.160) decreased with the duration of follow-up. Assuming mean age at menarche, BMI z-score significantly decreased with increasing baseline BMI z-score (β=−0.163, 95% CI −0.204 to −0.122) and a similar association was found between baseline BF% and changes in BF% (β=−0.294, 95% CI −0.341 to −0.248). Adiposity significantly increased with increasing age at menarche (BMI z-score: β=0.078, 95% CI 0.050 to 0.107; BF%: β=0.807, 95% CI 0.547 to 1.067), assuming mean adiposity at baseline, and with higher frequency of sports practice at baseline.

Among boys (table 3), assuming mean values of adiposity, higher duration of follow-up was associated with a decrease of BMI z-score (β=−0.010, 95% CI −0.017 to −0.002) and of BF% (β=−0.149, 95% CI −0.211 to −0.088). The association between baseline adiposity and its subsequent changes was statistically significant for both measures of adiposity, assuming mean duration of follow-up: higher values at baseline were associated with a subsequent decrease in adiposity (BMI z-score: β=−0.143, 95% CI −0.180 to −0.107; BF%: β=−0.414, 95% CI −0.458 to −0.370). Regarding parental BMI, BMI z-score significantly increased among boys

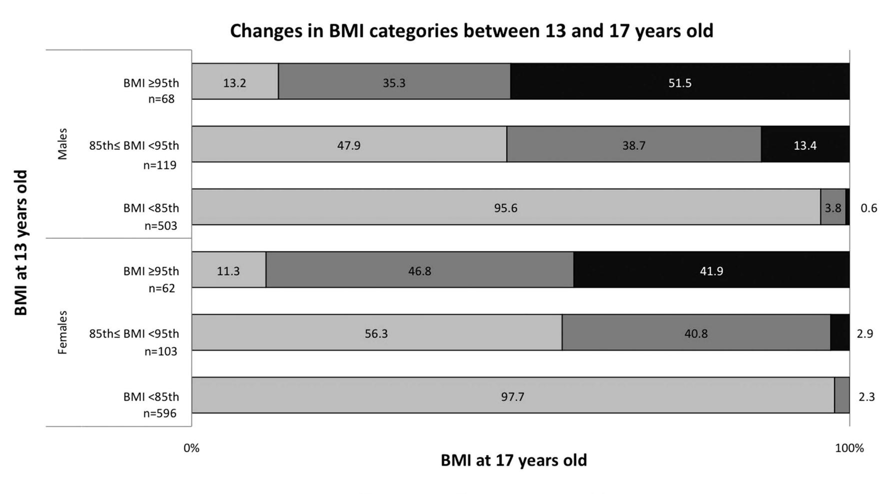

Figure 1 Distribution of body mass index (BMI) categories at the age of 17 according to BMI categories at the age of 13, defined by the US CDC criteria by sex.

Table 1 Characterisation of changes in BMI categories between the age of 13 and 17 years, according to baseline characteristics, by sex

Characteristics at 13 years	Changes in BMI categories from the age of 13 to 17 years—girls: Normal at both 582 (76.5%)	Overweight/obese at both 68 (8.9%)	Increasing 17 (2.2%)	Decreasing 94 (12.4%)	p Value	Changes in BMI categories from the age of 13 to 17 years—boys: Normal at both 481 (69.7%)	Overweight/obese at both 81 (11.7%)	Increasing 38 (5.5%)	Decreasing 90 (13.0%)	p Value
Age at menarche	12.0 (12.0–13.0)	12.0 (11.0–13.0)	13.0 (11.0–14.5)	12.0 (11.0–13.0)	0.024	–	–	–	–	
Parental education	11.0 (7.0–15.0)	9.5 (6.2–12.0)	9.0 (6.0–12.0)	9.5 (6.0–15.0)	0.339	12.0 (7.5–17.0)	12.0 (9.0–17.0)	11.5 (8.8–14.5)	11.0 (9.0–14.2)	0.698
Parental BMI (kg/m^2)										
<25.0	237 (40.7)	9 (13.2)	5 (29.4)	24 (25.5)	<0.001	169 (35.1)	23 (28.4)	9 (23.7)	19 (21.1)	<0.001
25.0–29.9	251 (53.1)	38 (55.9)	8 (47.1)	37 (39.4)		259 (53.8)	32 (39.5)	17 (44.7)	49 (54.4)	
≥30	94 (16.2)	21 (30.9)	4 (23.5)	33 (35.1)		53 (11.0)	26 (32.1)	12 (31.6)	22 (24.4)	
TV at weekend (min)										
≤120	122 (22.7)	7 (11.1)	0	13 (15.9)	0.061	94 (21.2)	16 (22.2)	10 (29.4)	13 (16.0)	0.574
121–240	185 (34.5)	21 (33.3)	7 (43.8)	31 (37.8)		157 (35.4)	27 (37.5)	11 (32.4)	23 (28.4)	
241–360	131 (24.4)	20 (31.7)	6 (37.5)	15 (18.3)		99 (22.3)	18 (25.0)	7 (20.6)	22 (27.2)	
>360	99 (18.4)	15 (23.8)	3 (18.8)	23 (28.0)		94 (21.2)	11 (15.3)	6 (17.6)	23 (28.4)	
Leisure time activities										
Mainly sitting	167 (31.3)	23 (36.5)	1 (6.3)	28 (32.9)	0.040	110 (25.3)	24 (35.8)	9 (26.5)	24 (30.8)	0.095
Mainly standing	150 (28.1)	19 (30.2)	10 (62.5)	30 (35.3)		55 (12.7)	9 (13.4)	3 (8.8)	17 (21.8)	
Active or very active	217 (40.6)	21 (33.3)	5 (31.3)	27 (31.8)		269 (62.0)	34 (50.7)	22 (64.7)	37 (47.4)	
Regular practice of sports										
Never	153 (26.7)	20 (29.9)	1 (6.3)	25 (27.2)	0.180	49 (10.4)	8 (10.4)	1 (2.9)	10 (11.2)	0.013
≤1 times/week	147 (25.7)	18 (26.9)	6 (37.5)	30 (32.6)		70 (14.9)	13 (16.9)	12 (34.3)	17 (19.1)	
2–3 times/week	189 (33.0)	23 (34.3)	7 (43.8)	19 (20.7)		152 (32.3)	31 (40.3)	8 (22.9)	39 (43.8)	
>3 times/week	84 (14.7)	6 (9.0)	2 (12.5)	18 (19.6)		199 (42.3)	25 (32.5)	14 (40.0)	23 (25.8)	
Body image discrepancy*										
≥1	141 (25.8)	56 (87.5)	7 (43.8)	79 (86.8)	<0.001	70 (15.8)	63 (86.3)	20 (55.6)	69 (83.1)	<0.001
0	293 (53.6)	8 (12.5)	9 (56.3)	12 (13.2)		167 (37.7)	9 (12.3)	15 (41.7)	12 (14.5)	
≤−1	113 (20.7)	0	0	0		206 (46.5)	1 (1.4)	1 (2.8)	2 (2.4)	

*Perceived minus desired figure: ≥1 desired thinner than perceived figure, ≤−1 desired larger than perceived figure.
Data are presented as median (25th–75th centiles) for continuous variables and n (%) for categorical variables.
BMI, body mass index; TV, television.

Table 2 Association between baseline characteristics and changes in BMI z-scores and in body fat percentage among girls

	N	Changes in BMI z-scores: Crude β (95% CI)	Changes in BMI z-scores: Adjusted β (95% CI)*	Changes in body fat percentage: Crude β (95% CI)	Changes in body fat percentage: Adjusted β (95% CI)†
Baseline BMI z-score	761	−0.164 (−0.205 to −0.123)‡	−0.163 (−0.204 to −0.122)	–	–
Baseline BF%	761	–	–	−0.298 (−0.345 to −0.250)‡	−0.294 (−0.341 to −0.248)
Age at menarche	761	0.078 (0.049 to 0.107)‡	0.078 (0.050 to 0.107)	0.802 (0.533 to 1.071)‡	0.807 (0.547 to 1.067)
BMI z-score×age at menarche	761	−0.059 (−0.088 to −0.030)‡	−0.059 (−0.088 to −0.031)	–	–
Baseline BF%×age at menarche	761	–	–	−0.037 (−0.069 to −0.004)‡	−0.037 (−0.068 to −0.005)
Duration of follow-up	761	−0.008 (−0.015 to −0.002)	−0.008 (−0.014 to −0.002)	−0.231 (−0.302 to −0.159)	−0.221 (−0.282 to −0.160)
Parental education	761	0.002 (−0.006 to 0.010)	0.001 (−0.006 to 0.008)	0.058 (−0.028 to 0.145)	0.010 (−0.062 to 0.082)
Parental BMI (kg/m^2)					
<25.0	275	0	0	0	0
25.0–29.9	334	−0.093 (−0.170 to −0.017)	−0.014 (−0.086 to 0.057)	−0.813 (−1.675 to 0.048)	0.189 (−0.537 to 0.915)
≥30	152	−0.100 (−0.195 to −0.005)	0.027 (−0.064 to 0.118)	−1.980 (−3.049 to −0.910)	−0.273 (−1.196 to 0.649)
TV at weekend (min)					
≤120	142	0	0	0	0
121–240	244	0.051 (−0.049 to 0.150)	0.064 (−0.026 to 0.155)	0.845 (−0.279 to 1.968)	1.020 (0.096 to 1.944)
241–360	172	0.038 (−0.069 to 0.145)	0.064 (−0.033 to 0.162)	0.330 (−0.877 to 1.536)	0.874 (−0.120 to 1.868)
>360	140	−0.029 (−0.141 to 0.083)	0.030 (−0.073 to 0.133)	−0.185 (−1.453 to 1.082)	0.659 (−0.392 to 1.711)
Leisure-time activities					
Mainly sitting	219	0	0	0	0
Mainly standing	209	−0.017 (−0.109 to 0.074)	0.007 (−0.076 to 0.091)	−0.734 (−1.755 to 0.288)	−0.294 (−1.143 to 0.556)
Active or very active	270	0.050 (−0.036 to 0.136)	0.012 (−0.066 to 0.091)	1.209 (0.248 to 2.169)	0.497 (−0.304 to 1.297)
Regular practice of sports					
Never	199	0	0	0	0
≤1 times/week	201	0.012 (−0.082 to 0.106)	−0.015 (−0.101 to 0.070)	0.535 (−0.524 to 1.594)	0.135 (−0.740 to 1.011)
2–3 times/week	238	0.141 (0.051 to 0.231)	0.104 (0.020 to 0.187)	1.778 (0.761 to 2.795)	1.184 (0.331 to 2.037)
>3 times/week	110	0.089 (−0.022 to 0.200)	0.049 (−0.054 to 0.152)	1.550 (0.293 to 2.808)	0.656 (−0.397 to 1.709)
Body image discrepancy§					
≥1	283	−0.144 (−0.218 to −0.070)	−0.015 (−0.094 to 0.064)	−1.706 (−2.547 to −0.865)	0.685 (−0.105 to 1.475)
0	322	0	0	0	0
≤−1	113	0.224 (0.125 to 0.323)	0.013 (−0.093 to 0.119)	2.302 (1.173 to 3.431)	−0.046 (−1.074 to 0.982)

*Adjusted for baseline BMI z-score, duration of follow-up, parental education, age at menarche and the interaction term (baseline BMI z-score×age at menarche).
†Adjusted for baseline BF%, duration of follow-up, parental education, age at menarche and the interaction term (baseline BF%×age at menarche).
‡Crude estimates for these variables were obtained with the three variables at the same time in the model.
§Perceived minus desired figure: ≥1 desired thinner than perceived figure, ≤−1 desired larger than perceived figure.
BMI, body mass index; BF%, body fat percentage; TV, television.

Table 3 Association between baseline characteristics and changes in BMI z-scores and in body fat percentage among boys

		Changes in BMI z-scores		Changes in body fat percentage	
	n	Crude β (95% CI)	Adjusted β (95% CI)*	Crude β (95% CI)	Adjusted β (95% CI)†
Baseline BMI z-score	690	−0.143 (−0.180 to −0.107)‡	−0.143 (−0.180 to −0.107)	–	–
Baseline BF%	690	–	–	−0.414 (−0.458 to −0.370)‡	−0.414 (−0.458 to −0.370)
Duration of follow-up	690	−0.009 (−0.017 to −0.002)‡	−0.010 (−0.017 to −0.002)	−0.153 (−0.214 to −0.092)‡	−0.149 (−0.211 to −0.088)
BMI z-score×duration follow-up	690	−0.011 (−0.019 to −0.004)‡	−0.011 (−0.019 to −0.003)	–	–
BF%×duration follow-up	690	–	–	−0.020 (−0.029 to −0.012)‡	−0.021 (−0.029 to −0.012)
Parental education	690	−0.002 (−0.010 to 0.007)	−0.003 (−0.011 to 0.005)	0.058 (−0.028 to 0.144)	0.026 (−0.043 to 0.095)
Parental BMI (kg/m^2)					
<25	220	0	0	0	0
25–29.9	357	−0.005 (−0.092 to 0.081)	0.015 (−0.067 to 0.097)	0.178 (−0.706 to 1.061)	0.521 (−0.180 to 1.221)
≥30	113	0.030 (−0.087 to 0.147)	0.127 (0.012 to 0.241)	−0.291 (−1.483 to 0.902)	1.526 (0.559 to 2.492)
TV at weekend (min)					
≤120	133	0	0	0	0
121–240	218	−0.016 (−0.127 to 0.096)	−0.033 (−0.138 to 0.073)	−0.271 (−1.406 to 0.864)	−0.318 (−1.218 to 0.582)
241–360	146	−0.073 (−0.194 to 0.049)	−0.068 (−0.184 to 0.048)	−0.660 (−1.897 to 0.576)	−0.394 (−1.385 to 0.598)
>360	134	−0.008 (−0.132 to 0.116)	−0.021 (−0.142 to 0.100)	−0.366 (−1.629 to 0.896)	−0.327 (−1.361 to 0.706)
Leisure-time activities					
Mainly sitting	167	0	0	0	0
Mainly standing	84	−0.110 (−0.245 to 0.025)	−0.123 (−0.250 to 0.004)	−1.022 (−2.395 to 0.351)	−1.083 (−2.172 to 0.007)
Active or very active	362	0.084 (−0.010 to 0.178)	0.048 (−0.042 to 0.137)	0.516 (−0.444 to 1.476)	−0.403 (−1.171 to 0.365)
Regular practice of sports					
Never	68	0	0	0	0
≤1 times/week	112	0.048 (−0.107 to 0.202)	0.048 (−0.098 to 0.194)	−0.615 (−2.188 to 0.959)	−0.025 (−1.283 to 1.234)
2–3 times/week	230	−0.051 (−0.190 to 0.087)	−0.031 (−0.162 to 0.100)	−0.971 (−2.383 to 0.442)	−0.457 (−1.588 to 0.674)
>3 times/week	261	0.126 (−0.011 to 0.263)	0.113 (−0.017 to 0.243)	0.619 (−0.774 to 2.012)	0.189 (−0.927 to 1.304)
Body image discrepancy§					
≥1	222	−0.193 (−0.289 to −0.098)	−0.096 (−0.199 to 0.006)	−3.416 (−4.366 to −2.467)	0.691 (−0.232 to 1.613)
0	203	0	0	0	0
≤−1	210	0.104 (0.007 to 0.201)	−0.002 (−0.106 to 0.102)	−0.049 (−1.011 to 0.914)	−1.367 (−2.174 to −0.560)

*Adjusted for baseline BMI z-score, duration of follow-up, parental education and the interaction term (baseline BMI z-score×duration of follow-up).
†Adjusted for baseline BF%, duration of follow-up, parental education and the interaction term (baseline BF%×duration of follow-up).
‡Crude estimates for these variables were obtained with the three variables at the same time in the model.
§Perceived minus desired figure: ≥1 desired thinner than perceived figure, ≤−1 desired larger than perceived figure.
BMI, body mass index; BF%, body fat percentage; TV, television.

with parents with a higher BMI (BMI≥30 kg/m^2: β=0.127, 95% CI 0.012 to 0.241, compared with BMI<25.0 kg/m^2) as well as BF% (BMI≥30 kg/m^2: β=1.526, 95% CI 0.559 to 2.492). Boys who reported a desired body image larger than perceived significantly decreased their BF% at follow-up (β=−1.367, 95% CI −2.174 to −0.560), compared with those who reported similar desired and perceived body images (table 3).

DISCUSSION

Our results documented a decrease in BMI z-score and in BF% from the age of 13 to 17 years, in both sexes. As we used the CDC Growth Charts[23] as reference for the calculation of BMI z-scores, our results show that adolescents in Porto, Portugal, at these ages increase in body size slightly less quickly than the US adolescents do. In terms of changes in BMI categories, the decrease is expressed by 51.8% of overweight and 53.1% of obese adolescents switching to a lower category of BMI. Despite this declining trend, 2.2% of girls and 5.5% of boys switched to a higher category of BMI, and among those obese at the age of 13, 41.9% of girls and 51.5% of boys were still obese at the age of 17. Beyond changes in BMI categories we also studied changes in BMI z-scores using the continuous variable. This approach allowed the detection and characterisation of all changes in BMI that occurred in this 4-year period, not only those that resulted in the change of BMI category. Changes in the BMI categories could reflect only the changes occurring among participants with BMI closer to the cut-offs of each category.

BMI z-scores were calculated based on the US reference, because it was the reference adopted in Portugal by the national health authorities at the time. However, we also calculated age-specific and sex-specific BMI z-scores according to the WHO Growth reference data for 5–19 years[27] (data not shown) in order to test whether our results were dependent on the reference population we chose. Using the WHO reference, we also found a mean decrease in BMI z-scores and similar associations with its determinants, reinforcing the validity of our results.

As BMI does not distinguish fat from fat-free mass,[20 21] we also decided to evaluate changes in BF%, measured by foot-to-foot bioelectrical impedance. Although bioelectrical impedance of two components is not the reference method, it provides more accurate estimates of fat mass than BMI.[28] We also found a decrease in BF% from the age of 13 to 17 years and similar determinants of its decrease, supporting the results found with BMI.

In the US National Longitudinal Study of Adolescent Health, obesity incidence over the 5-year period between the waves II (13–20 years) and III (19–26 years) was 12.7%.[12] In the Bogalusa Heart Study[19] the risk of overweight adolescents (13–17 years) becoming overweight young adults (27–31 years) ranged from 52% to 62%. Other smaller studies showed that childhood and adolescence overweight tend to persist or track into adulthood[5 19 29] and that adolescent obesity is a better predictor of adult obesity than childhood obesity.[9 30] In our study the proportion of adolescents who decreased their BMI was higher than those who increased it. However, it is important to emphasise that in our study we also found a large proportion of adolescents who remained overweight or obese, supporting the idea that overweight tends to persist. As we evaluated a short period of the adolescence course, it is possible that BMI decreases in mid adolescence but a subsequent increase follows in young adulthood. As described before, previous studies with a longer duration of follow-up have shown that adolescent overweight is positively associated overweight in adulthood.[9 12 19] The participants of our study will be re-evaluated at 21 years of age and this information will be important to understand the trajectories of BMI until adulthood.

A possible explanation for the decrease in adiposity found in our sample could be the regression to the mean effect,[31] which occurs when repeated measurements are made on the same participant and because values are observed with random error. However, this statistical phenomenon is more relevant when baseline and follow-up measurements are less correlated,[31 32] which is not the case in our study; the correlation coefficient was about 0.8 for BMI z-score and 0.7 for BF%. Additionally, we quantified the regression to the mean effect[31] in our sample, assuming as the cut-off the 85th centile from CDC reference for BMI and the 85th centile of our sample for BF%. We found that the estimated regression to the mean effect for BMI z-score (0.04 SD in girls and 0.05 SD in boys) was much lower than the mean decrease found in our sample (−0.20 SD, 95% CI −0.23 to −0.16 in girls and −0.15 SD, 95% CI −0.19 to −0.11 in boys). For the change in BF%, the estimated regression to the mean effect was 0.48% in girls and 0.39% in boys, and the mean differences were −1.33% (95% CI −1.71 to −0.94) and −1.46% (95% CI −1.85 to −1.07), respectively. These data indicate that our results are not explained by this statistical phenomenon.

The decrease in adiposity documented here may result from the fact that we are evaluating the period from 13 to 17 years of age. At the age of 13, the increase in fat mass percentage expected by the physiological changes related with puberty in girls had mostly occurred. For boys, during this period (between the age of 13 and 17 years), the expected physiological changes related with puberty represent an increase in fat-free mass.[33] Despite chronological age not being the best measure of pubertal development, it was used as a proxy since Tanner evaluation was not performed. We also used the age of menarche in girls to characterise pubertal development and we found an interaction effect between age at menarche and baseline adiposity in association with changes in adiposity. For mean values of adiposity at baseline, the later the age at menarche, the greater was the increase in BMI and in BF% from the age of 13 to 17 years. Oppositely, an earlier age at menarche was associated with higher odds of being overweight at the age of 13.[22] Based on these results we could suppose that girls with a later age at menarche are less likely to be overweight at the age of 13 because the weight gain related with puberty occurs later; for this group the increase in BMI and BF% seems to happen between the age of 13 and 17 years. This corroborates the fact that the decrease in adiposity is partly explained by pubertal development, because for the same chronological age, those with later maturation are still experiencing an increase in BF%.

It is well known that adolescents are particularly susceptible to social pressures, mostly concerning body image.[16 17] These pressures could lead to the adoption of strategies to lose weight, such as dieting,[16] particularly among girls, that would contribute to the explanation of the observed trends. Girls with higher baseline BMI z-score presented lower BMI z-score at follow-up. Additionally, girls who had a desired image thinner than perceived were more likely to decrease their BMI z-score and their BF% than those who perceived themselves as desired. However, this significant association disappeared after adjustment, suggesting that the effect of body image was mediated by baseline BMI z-score. A previous cross-sectional analysis in our sample showed that body image dissatisfaction was associated with BMI.[26]

In boys, a desired body image larger than perceived significantly decreased their BF% at follow-up. This could be explained by the inability of the Stunkard silhouettes to distinguish fat mass from fat-free mass[34 35]; boys reporting a desired body image larger than perceived could express the desire to be stronger and not fatter.[35–37] Thus, as boys want to be more robust, they might practice more sports and because of that they decrease their body fat and increase their fat-free mass, without significant differences in BMI.

As in other studies,[9 38 39] we found that the higher the parental BMI, the higher the increase in adolescent BMI, but the results reach statistical significance only in boys. Parental BMI might be an indicator of the family environment, favouring or not obesity development, beyond of a genetic exposure.

Since adiposity at the age of 13 was the strongest determinant of adiposity at the age of 17, our models were adjusted for baseline adiposity (BMI z-score/BF%) in order to evaluate the effect of other characteristics, beyond its effect on previous adiposity. On the other hand, although the period of follow-up in our study was relatively short (approximately 4 years), the age of participants under study is characterised by marked changes in short periods of time, so the adjustment for duration of follow-up was also performed.

We analysed the associations between baseline characteristics and changes in adiposity. However, we need to notice that changes in some exposures, such as sedentary behaviour, could have also occurred between the two evaluations. Then, further models including the changes in behaviours between baseline and follow-up were explored (data not shown). In general, when the change was considered the results were similar because only a small proportion of adolescents changed their exposures. Nevertheless, among girls, the positive association found between regular practice of sports at the age of 13 and changes in BMI z-scores and in BF% lost significance when we considered the changes in regular practice of sports. Between the age of 13 and 17 years, 28.4% of girls increased while 35% decreased their frequency of regular practice of sports. Although associations did not reach statistical significance, those who increased their frequency decreased their BMI z-score and their BF% during that period and those who decreased their frequency increased these outcomes. These data are important to clarify that the result found may be due to changes in practice of sports from the age of 13 to 17 years.

Study limitations and strengths

We need to acknowledge some limitations of our study, such as the exclusion of some participants due to missing data. Despite these exclusions, the participants excluded were similar to those included in this analysis, except for the type of school they went to and parental education. Although these data suggest that excluded adolescents are from lower social classes, this could have a small effect on our results, since changes in BMI seem to be independent of parental education (used as an indicator of social class). Other limitation relates to the inability of assessing Tanner stages in our sample due to logistic constraints. However, in girls we used age at menarche as a proxy for pubertal development. With regard to the assessment of adiposity, BF% was obtained through bioelectrical impedance which is not the reference method, but it has been described as a reliable field method, specially in large groups.[28] On the other hand, our work has important strengths. It is population based and it was conducted on a large representative sample of adolescents, because school education is compulsory in our country until 15 years of age and we had a high rate of participation. At the age of follow-up evaluation school education was not compulsory; nevertheless, we re-evaluated 79.4% of baseline participants.

The same age of participants at baseline (13 years) and the short period of follow-up is an advantage of our study because it implies a more homogeneous sample. This could be particularly important to show an evolution in BMI that might occur in a short period of time during adolescence between puberty and early adulthood. This effect might not be found in studies with a wide age range of participants and with higher periods of follow-up, where the effect would be diluted.

CONCLUSION

In summary, BMI z-scores and BF% decreased from the age of 13 to 17 years showing that there is no definite deterministic effect of early conditions. However, the main determinants of the decrease were BMI and body fat values at baseline, which reinforces the need for timely interventions. These results also emphasise the importance of interventions in adolescence to prevent overweight and obesity in adulthood, taking advantage of the decrease in BMI and body fat or the delay in their increase, which is usually described from adolescence to adulthood.

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