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Does smoking in adolescence affect body mass index, waist or height? Findings from a longitudinal study

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ABSTRACT

Aim To assess the effect of smoking uptake on body mass index (BMI), waist circumference and height during adolescence. **Design** Five-year longitudinal study. **Setting** Thirty-six schools in South London, England, selected by a stratified random sampling procedure designed to ensure ethnic and socio-economic diversity. **Participants** A total of 5863 students took part in the HABITS (Health and Behaviour in Teenagers) Study between 1999 and 2003. **Measurements** Self-reported smoking behaviour, saliva cotinine concentrations and measured weight, waist circumference and height were obtained, along with information on gender, ethnicity, socio-economic deprivation, pubertal status, self-reported exercise and dieting. Students were examined annually from school year 7 (ages 11–12) to year 11 (ages 15–16), with response rates ranging from 74 to 84%. A total of 2665 never smokers at year 7 with complete data for years 7 and 11 were included in the analyses. **Findings** Adjusting for year 7 BMI and other potential confounders, regular smokers (more than six cigarettes a week) at year 11 had significantly lower BMI ($P = 0.002$) than other students. Smokers defined by a cotinine above 15 ng/ml also had lower BMI ($P < 0.0001$). Waist circumferences were lower in regular smokers ($P = 0.014$) and cotinine-defined smokers ($P < 0.011$). No consistent association was found between smoking and height. The adjusted difference in weight between regular smokers and other students amounted to 1.8 kg (95% CI, 0.52–3.17) for an average-height student. **Conclusion** Taking up regular smoking during adolescence may result in a lower BMI, but the effect is small and of uncertain significance.

Keywords Adolescence, BMI, height, longitudinal, smoking, waist, weight.

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INTRODUCTION

Many adolescents believe that smoking helps to keep them slim [1–3]. They are more likely to take up smoking if they perceive being thin as important [4], are concerned about their weight [5–8] or are trying to lose weight [5,9,10].

Although research typically finds a relationship between smoking and weight among adults, with smokers weighing between 1.1 and 6.8 kg (2.4–15 lb) less than non-smokers [11], it is not clear whether this is due to confounding factors. For example, people who take up smoking may already be on a trajectory of lower body weight before they started. Indeed, a recent review [12] has concluded that adolescent smokers either have a higher body mass index (BMI) [13,14], or are no different in weight from non-smokers [15,16]. Short of conducting an unethical experimental study, the only way to determine whether smoking indeed results in a lower body weight is to conduct a longitudinal study from before smoking initiation and follow weight trajectories as a function of smoking status, while controlling for as many potential confounding variables as possible.

Only two longitudinal studies have assessed whether smoking affects weight change over time among adolescents. Cooper *et al.* followed 1697 12–13-year-olds for 4 years, finding that adolescents smoking for up to 3 years showed no reduction in BMI, while those smoking for just 2 years increased their BMI compared with never-smokers [17]. However, this study relied on self-reported smoking, height and weight, which may lack the precision required to detect small but significant changes in weight between smokers and non-smokers, and did not measure pubertal stage or socio-economic deprivation,

which are potential confounding variables. Stice & Martinez [18] assessed the effect of persistent daily smoking on measured growth over a 1-year period among 496 girls aged 11–15. They found lower growth in weight, height and BMI in smokers, equivalent to 1.5 kg in weight and 1.0 cm in height, in analyses that controlled for ethnicity, parental education, timing of menarche, age, intake of high-fat foods and baseline BMI [18]. In addition they observed a dose–response relationship, with increased smoking frequency associated with lower gains in height, weight and BMI. Although the observed effect was not large, Stice & Martinez argued that the cumulative effect of smoking behaviour on growth could be substantial.

The present study assessed the longitudinal relationship between validated measures of smoking status and measured height and adiposity change over 4 years in a large, mixed-sex cohort of adolescents controlling for a wide range of potential confounding variables.

METHODS

Adolescents from 36 secondary schools in South London taking part in the HABITS (Health and Behaviour in Teenagers) Study had their heights, weights and waist circumferences measured, completed questionnaires and provided saliva samples for cotinine analysis. Cotinine is a quantitative measure of the amount of nicotine ingested in preceding days. Data were collected annually for 5 years, the first wave of measurement taking place in 1999 when students were aged 11–12 years. Students could decide not to take part and parents could withdraw their child's participation. Ethical approval was granted by the University College London/University College London Hospitals Medical Ethics Committee. More details of the procedure and sampling technique can be found in Wardle *et al.* [19].

Sample

Schools were selected randomly from a sampling frame designed to produce a socio-economically and ethnically diverse sample. All students present on the testing day each year were eligible to take part, with response rates of over 80% each year, except at the final year when the response rate was 74% because of two schools dropping out of the study and an increased number of students not present in class due to examination and placement commitments. A total of 5863 students participated in the study, 2787 of whom were present both at baseline (UK year 7, US grade 6) when students were 11–12 years of age and at the end of the study (UK year 11, US grade 10) when students were 15–16 years old. Of these, 2701 had BMI data at both year 7 and year 11 and smoking data at year 11. Because we were interested in the effect of uptake of smoking, 36 students who reported current smoking (smoking sometimes, or more often) in year 7 were excluded from analyses, bringing the total sample for analysis to 2665. Participants in this reduced sample of 2665 were more likely to be white ($P < 0.0001$), less socio-economically deprived ($P < 0.0001$) and to reach mid-puberty later ($P < 0.0001$) than those not included in analyses. In addition they were less likely to be current smokers at year 11 ($P = 0.004$), and had a lower BMI and smaller waist circumference in both year 7 ($P < 0.0001$) and year 11 ($P < 0.0001$).

Measures

Anthropometric measures

Weight measurements were taken to the nearest 0.1 kg using Tanita scales (Tanita UK Ltd, Yiewsley, Middx, UK). Height was measured using Leicester freestanding stadiometers, and waist circumference with a non-elastic tape to the nearest 0.1 cm. Students were measured in light indoor clothing without shoes. Height and weight were converted into BMI (weight (kg)/height $(m)^2$). To control for gender and age differences in the natural increase in BMI across the adolescent years, age-specific BMI standard deviation (SD) scores, as well as waist and height SD scores, were calculated according to the British 1990 growth reference curves, where scores in 1990 had a mean of zero and a SD of 1 [20]. BMI SD scores above zero therefore show a BMI greater than expected for a boy or girl of a specific age compared to the 1990 reference population. As BMI SD scores are age-adjusted, they should theoretically remain stable with age. Observed increases in SD score with age therefore suggest more rapid growth than adolescents of the same age in 1990.

Smoking

Self-reported smoking was assessed each year with a six-item scale (I have never smoked; I have only ever tried smoking once; I used to smoke sometimes but I never smoke cigarettes now; I sometimes smoke cigarettes now but I don't smoke as many as one a week; I usually smoke between one and six cigarettes a week; I usually smoke more than six cigarettes a week). In the following analyses, 'regular' smoking was defined as smoking more than six cigarettes a week. 'Current' smoking is defined as smoking 'sometimes', smoking 'one to six cigarettes a week' or smoking 'more than six cigarettes a week'. Students also provided a saliva sample on a cotton wool roll for cotinine assay as an objective assessment of nicotine intake.

Pubertal status

Pubertal stage was assessed using the Pubertal Development Scale [21], a summed score based on student ratings of growth spurt, pubic hair growth, skin changes, menarche and breast development (girls), and voice change and facial hair growth (boys). In these analyses we have designated puberty as 'early', 'average' or 'late', defining 'average' relative to the modal school year when 'mid-puberty' is reached for each sex.

Diet and exercise

A number of factors relating to energy intake and expenditure were assessed. For physical activity, students were asked 'on how many of the past 7 days did you do hard exercise or physical activities for at least 20 minutes that made you sweat and breathe hard (e.g. football, running, swimming)?' [22]. Sedentary behaviour was based on the total number of hours of television watched per week [23]. Restrained eating was assessed with the Dutch Eating Behaviour Questionnaire (DEBQ) [24] and dieting by whether students reported dieting to lose weight.

Socio-demographic factors

Students' postcodes (zipcodes) were converted to Townsend scores, a measure of socio-economic deprivation based on census reports of car ownership, housing tenure, unemployment and overcrowded living conditions in the residential neighbourhood. Scores were split into quintiles from least to most deprived [25]. Ethnic background was self-reported and categorized into white, black/mixed black, Asian/mixed Asian and 'other'.

Statistical analysis

Linear mixed-model analyses in SPSS 14 were used to test whether regular smoking in year 11 was associated with BMI, waist circumference and height in year 11 using year 7 BMI, waist circumference and height, respectively, as covariates. This procedure takes account of clustering within schools. Using only year 11 smoking data minimized loss of subjects due to non-inclusion in the intervening years, at the cost of not being able to assess the effect of number of years of smoking or changes in smoking status in the intervening years. In fact, regular smoking, once initiated, was quite stable: only 40 participants across the 5 years of the study moved from regular smoking at 1 year to non-current smoking at the next, and examination of each year's smoking data shows that the majority of year 11 smokers had reported current smoking for 2 or more years. The use of smoking behaviour at the end of the study was therefore the most practical method of identifying students who started and maintained cigarette smoking for a number of years while minimizing loss due to missing data. All analyses were restricted to those who were not current smokers at year 7 (i.e. never smokers, one-time triers and ex-smokers), to ensure no effect of smoking on weight before the study period.

Analyses were repeated replacing smoking status with year 11 saliva cotinine scores, giving an objective indication of nicotine intake. Cotinine scores were dichotomized at 15 ng/ml, a value used typically to indicate smoking behaviour [26]. Finally, adjusted analyses were run including age, pubertal status, dieting, restrained eating and exercise behaviour at year 11 as well as gender, ethnicity and deprivation. The procedure was then repeated using BMI, waist and height SD scores. Where outliers resulted in departure from the normal distribution, variables were transformed using log-transformation.

As a further check on the robustness of the models, the mixed-model analyses were repeated using smoking, BMI, waist and height measurements in each year that data were available and interactions run between smoking and study year. This permitted data to be included for any years in which students were present, even though they may not have been present on all occasions. It provides an indication of the difference in BMI, waist and height trajectories by smoking status. Using year 11 BMI, waist and height as the main outcome allows a transparency of findings that are accessible and simple to interpret.

RESULTS

There were more boys (57.9%, $n = 1543$) than girls (42.1%, $n = 1122$) in the final sample. They were ethnically diverse, with 63.1% white, 23.0% black or mixed black, 11.2% Asian or mixed Asian and 2.6% of other ethnic background (two participants did not report their ethnic group). Table 1 shows the percentage of students in each smoking status group at year 11 as well as the distribution of potential confounding variables across smoking groups. At year 11 just over a third of participants (37.3%) were never smokers, 29.2% were current smokers (smoking sometimes or more often) and almost 10% reported regular smoking. Table 1 also shows that more girls reported smoking than boys, more white students reported smoking than non-white students, earlier puberty was associated with higher levels of smoking and the least-deprived students were most likely to have never smoked, although the relationship between deprivation and smoking is not clear, with the most deprived students not showing high levels of regular smoking. Regular smoking was associated with higher restrained eating and lower levels of sedentary behaviour, although also lower physical activity.

Table 1 Smoking status at year 11 by potential confounding variables, percentage (*n*).

	Never smoked	*Tried once*	*Used to smoke*	*Sometimes smoke*	*Smoke 1–6 a week*	*Smoke > 6 a week*	χ^2/*ANOVA test*
Total sample	37.3 (993)	22.8 (608)	10.7 (286)	14.1 (375)	5.4 (144)	9.7 (259)	
Gender							
Boys	39.9 (615)	23.2 (358)	10.0 (154)	13.2 (203)	5.1 (79)	8.7 (134)	$\chi^2 = 15.56$, df = 5,
Girls	33.7 (378)	22.3 (250)	11.8 (132)	15.3 (172)	5.8 (65)	11.1 (125)	$P = 0.008$
Ethnicity							
White	33.4 (561)	20.6 (346)	11.2 (188)	16.2 (273)	6.4 (108)	12.2 (205)	$\chi^2 = 118.89$, df = 15,
Black	42.1 (258)	29.7 (182)	11.6 (71)	9.1 (56)	2.9 (18)	4.6 (28)	$P < 0.0001$
Asian	51.8 (155)	20.4 (61)	6.0 (18)	12.0 (36)	5.0 (15)	4.7 (14)	
Other	27.1 (19)	27.1 (19)	12.9 (9)	14.3 (10)	4.3 (3)	14.3 (10)	
Deprivation							
Least deprived	39.4 (245)	20.7 (129)	8.8 (55)	16.9 (105)	3.9 (24)	10.3 (64)	$\chi^2 = 44.41$, df = 20,
Quintile 2	36.5 (188)	20.2 (104)	11.3 (58)	14.4 (74)	7.6 (39)	10.1 (52)	$P = 0.001$
Quintile 3	38.5 (180)	19.7 (92)	12.0 (56)	15.2 (71)	5.4 (25)	9.2 (43)	
Quintile 4	35.7 (158)	22.3 (99)	11.1 (49)	13.3 (59)	5.9 (26)	11.7 (52)	
Most deprived	36.1 (220)	29.8 (182)	11.0 (67)	10.7 (65)	4.8 (29)	7.7 (47)	
Pubertal stage							
Early	33.8 (274)	23.3 (189)	11.0 (89)	13.8 (112)	5.8 (47)	12.2 (99)	$\chi^2 = 27.19$, df = 10,
Normal	35.2 (338)	23.4 (224)	12.2 (117)	14.1 (135)	6.3 (60)	8.9 (85)	$P = 0.002$
Late	42.6 (378)	21.7 (193)	9.0 (80)	14.2 (126)	4.2 (37)	8.3 (74)	
Dieting							
Yes	32.3 (114)	21.8 (77)	14.2 (50)	15.3 (54)	4.8 (17)	11.6 (41)	$\chi^2 = 9.68$, df = 5,
No	38.2 (860)	22.8 (512)	10.3 (232)	13.9 (313)	5.6 (125)	9.2 (208)	$P = 0.085$
Days vigorous exercise mean (SD)	2.7 (2.0)	2.6 (1.9)	2.9 (2.0)	2.7 (1.8)	2.6 (1.9)	2.2 (1.9)	$F = 4.19$, df = 5,2592, $P = 0.001$
Hours of TV mean (SD)	16.0 (8.5)	16.1 (8.7)	16.9 (8.1)	15.3 (7.8)	14.5 (7.9)	14.2 (8.7)	$F = 4.07$, df = 5,2577, $P = 0.001$
Restrained eating score mean (SD)	6.7 (3.3)	7.1 (3.5)	7.7 (3.8)	7.5 (3.6)	7.6 (3.7)	8.1 (4.2)	$F = 9.20$, df = 5,2584, $P < 0.0001$

Mean BMI, waist circumference and height at year 7 and year 11, by gender and by year 11 smoking status, are shown in Table 2, along with equivalent BMI SD, waist SD and height SD scores.

Mixed-model analysis showed that smoking status was associated significantly with year 11 BMI after adjusting for year 7 BMI ($P = 0.001$). Pubertal status, dieting behaviour, vigorous exercise, sedentary behaviour and restrained eating were associated with both smoking and BMI. However, the inclusion of these variables in the model, as well as gender, ethnicity, age and deprivation, did not change the results. Year 11 BMI was associated significantly with higher year 7 BMI ($P < 0.0001$), dieting to lose weight ($P < 0.0001$), sedentary behaviour ($P = 0.007$) and younger age ($P < 0.0001$), and the effect of smoking remained significant ($P = 0.002$). *Post-hoc* tests (Table 3) showed that the adjusted year 11 BMI of regular smokers was lower than that of all other smoking groups (never smokers, $P = 0.001$; once-only triers, $P = 0.009$; ex-smokers, $P = 0.005$; sometimes smokers, $P = 0.014$; and those smoking one to six cigarettes a week, $P = 0.036$). The BMI of regular smokers in this fully adjusted analysis was 0.66 BMI points (95% CI, 0.18–1.13) less than never smokers—a value equivalent to 1.84 kg (95% CI, 0.52–3.17) in a person of this age range of average height. As there was no effect of gender, and no interaction between gender and smoking status, separate analyses for boys and girls are not presented. Similarly, there was no interaction between ethnicity and smoking, nor between deprivation and smoking, therefore analyses were not stratified by these variables.

To confirm this finding using an objective measure of nicotine intake, analyses were carried out using cotinine levels ($n = 1751$). The association between high cotinine and lower year 11 BMI, adjusted for year 7 BMI and all other confounding factors, was significant ($P < 0.0001$). There was no evidence for a dose–response relationship above the 15 ng/ml cut-off value for smoking.

Repeating the analysis using age- and gender-adjusted BMI SD scores showed a similar pattern: regular smoking was associated with lower year 11 BMI SD score after adjusting for year 7 BMI SD score ($P = 0.006$) and other potential confounding variables ($P = 0.009$).

Using the same methodology, we looked at the effect of smoking on waist circumference. Controlling for waist

Table 2 Mean (SD) BMI, waist circumference and height by gender and year 11 smoking status.

				Year 11 smoking status					
	Boys	*Girls*	*Total*	*Never smoked*	*Tried once*	*Used to smoke*	*Sometimes smoke*	*Smoke 1–6 per week*	*Smoke > 6 per week*
BMI									
Year 7	18.9	19.8	19.3	19.3	19.2	19.4	19.1	18.8	19.7
	(3.2)	(3.7)	(3.4)	(3.5)	(3.4)	(3.5)	(3.3)	(2.8)	(3.5)
Year 11	21.8	22.6	22.1	22.2	22.1	22.4	21.9	21.8	22.0
	(3.7)	(4.0)	(3.8)	(4.0)	(3.8)	(4.1)	(3.5)	(3.4)	(3.7)
BMI SD score									
Year 7	0.43	0.44	0.43	0.43	0.44	0.47	0.35	0.31	0.58
	(1.18)	(1.20)	(1.18)	(1.23)	(1.17)	(1.20)	(1.14)	(1.00)	(1.2)
Year 11	0.52	0.56	0.53	0.55	0.54	0.59	0.48	0.46	0.50
	(1.10)	(1.11)	(1.10)	(1.15)	(1.09)	(1.16)	(1.02)	(1.02)	(1.05)
Waist (cm)									
Year 7	67.6	67.7	67.6	67.9	67.6	67.7	67.1	66.0	68.1
	(8.0)	(8.2)	(8.1)	(8.3)	(7.8)	(8.3)	(8.1)	(6.7)	(8.0)
Year 11	78.4	74.5	76.8	77.1	76.9	77.3	76.3	76.0	75.7
	(9.4)	(9.0)	(9.5)	(10.0)	(9.1)	(10.3)	(8.8)	(9.0)	(8.5)
Waist SD score									
Year 7	0.78	1.15	0.93	0.95	0.94	0.94	0.87	0.76	1.03
	(0.97)	(1.09)	(1.03)	(1.04)	(1.02)	(1.07)	(1.07)	(0.94)	(1.01)
Year 11	0.89	1.41	1.11	1.10	1.13	1.18	1.10	1.04	1.06
	(1.00)	(1.16)	(1.10)	(1.11)	(1.07)	(1.19)	(1.05)	(1.09)	(1.08)
Height (cm)									
Year 7	149.7	151.9	150.6	150.5	150.5	151.4	150.2	150.8	150.9
	(7.3)	(7.5)	(7.5)	(7.8)	(7.5)	(7.2)	(7.1)	(7.0)	(6.9)
Year 11	174.0	163.2	169.5	169.6	169.5	169.6	169.3	169.6	168.8
	(7.2)	(6.4)	(8.7)	(9.2)	(8.4)	(8.3)	(8.1)	(9.0)	(8.2)
Height SD score									
Year 7	0.33	0.42	0.37	0.38	0.36	0.45	0.27	0.37	0.41
	(1.00)	(1.00)	(1.00)	(1.07)	(0.99)	(0.96)	(0.95)	(0.96)	(0.93)
Year 11	0.19	0.03	0.12	0.08	0.12	0.19	0.15	0.16	0.11
	(0.93)	(1.04)	(0.98)	(1.05)	(0.95)	(0.94)	(0.93)	(0.99)	(0.90)

Note: there were no significant differences across smoking categories in the raw means for any of the above measures. BMI = body mass index.

circumference at year 7, regular smokers at year 11 had smaller waists ($P = 0.003$). In the fully adjusted model, the overall effect of smoking remained ($P = 0.014$), but significant differences between groups were restricted to the comparison between regular smokers and ex-smokers ($P = 0.015$) and regular smokers and those smoking one to six cigarettes a week ($P = 0.034$) (see Table 3). There were no significant interactions between smoking and gender, ethnicity or deprivation. Considering waist SD scores, the main effect of smoking on adjusted year 11 waist circumference was not significant ($P = 0.073$ adjusting for year 7 waist SD score, $P = 0.096$ including all covariates). However, a high cotinine value was associated with lower waist circumference ($P = 0.011$) and waist SD score ($P = 0.027$), with the mean adjusted waist circumference being 1.2 cm (95% CI, 0.28–2.16) lower among those with a high cotinine score.

Regular smokers at year 11 were shorter than other students adjusting for year 7 height ($P = 0.017$). An overall association remained with other potential confounding variables included ($P = 0.009$), but by pairwise comparison regular smokers showed no difference in adjusted height compared to other smoking groups. Again, there were no significant interactions between smoking and gender, ethnicity or deprivation. These results were replicated when using height SD scores ($P = 0.013$, $P = 0.001$, see Table 3) but there was no significant association between cotinine and fully adjusted height ($P = 0.500$) or height SD score ($P = 0.529$).

A small number of BMI and waist circumference outliers were identified, therefore analyses were re-run using log-transformations of BMI and waist values to correct for the departure from normality of the distribution. The results changed only slightly, with the difference between regular smokers and those smoking one to six cigarettes a week disappearing in both BMI ($P = 0.61$) and waist circumference ($P = 0.099$) analyses. This brought the BMI findings into line with those observed for BMI SD scores

Table 3 Estimated marginal means (95% confidence intervals) of BMI, waist circumference and height in year 11 by smoking status.

Year 11 smoking status	*Never smoked*	*Tried once*	*Used to smoke*	*Sometimes smoke*	*Smoke 1–6 per week*	*Smoke > 6 per week*
BMI						
Mean 1* (95% CI)	22.2[a]‡	22.1[a]	22.2[a]	22.1[a]	22.2[a]	21.5[b]
(*n* = 2665)	(22.0; 22.4)	(21.9; 22.3)	(21.9; 22.5)	(21.9; 22.4)	(21.9; 22.6)	(21.2; 21.8)
Mean 2† (95% CI)	22.4[a]	22.3[a]	22.4[a]	22.3[a]	22.4[a]	21.7[b]
(*n* = 2495)	(22.1; 22.6)	(22.0; 22.6)	(22.1; 22.7)	(22.0; 22.6)	(22.0; 22.9)	(21.4; 22.1)
BMI SD score						
Mean 1 (95% CI)	0.55[a]	0.54[a]	0.56[a]	0.55[a]	0.55[ab]	0.38[b]
(*n* = 2665)	(0.49; 0.60)	(0.48; 0.60)	(0.48; 0.64)	(0.48; 0.63)	(0.44; 0.66)	(0.29; 0.46)
Mean 2 (95% CI)	0.59[a]	0.57[a]	0.59[a]	0.60[a]	0.59[ab]	0.41[b]
(*n* = 2495)	(0.52; 0.66)	(0.49; 0.65)	(0.49; 0.68)	(0.51; 0.69)	(0.46; 0.71)	(0.31; 0.52)
Waist circumference (cm)						
Mean 1 (95% CI)	76.6[a]	76.6[a]	76.9[a]	76.7[a]	77.1[a]	74.9[b]
(*n* = 2674)	(75.7; 77.4)	(75.7; 77.5)	(75.9; 78.0)	(75.7; 77.7)	(75.8; 78.4)	(73.8; 76.0)
Mean 2 (95% CI)	76.6[ab]	76.7[ab]	77.1[a]	76.6[ab]	77.3[a]	75.2[b]
(*n* = 2504)	(75.8; 77.4)	(75.8; 77.5)	(76.1; 78.1)	(75.7; 77.6)	(76.0; 78.6)	(74.1; 76.3)
Waist SD score						
Mean 1 (95% CI)	1.08[a]	1.12[a]	1.15[a]	1.14[a]	1.18[a]	0.99[a]
(*n* = 2673)	(1.00; 1.16)	(1.03; 1.21)	(1.04; 1.26)	(1.04; 1.25)	(1.04; 1.32)	(0.87; 1.10)
Mean 2 (95% CI)	1.12[a]	1.15[a]	1.17[a]	1.15[a]	1.18[a]	0.99[a]
(*n* = 2503)	(1.03; 1.22)	(1.04; 1.25)	(1.05; 1.29)	(1.04; 1.27)	(1.03; 1.33)	(0.87; 1.12)
Height (cm)						
Mean 1 (95% CI)	169.1[a]	169.1[ab]	169.1[ab]	169.5[a]	168.6[ab]	167.9[b]
(*n* = 2681)	(167.2; 171.0)	(167.2; 171.0)	(167.2; 171.1)	(167.5; 171.4)	(166.6; 170.7)	(165.9; 169.9)
Mean 2 (95% CI)	167.4[a]	167.9[ab]	167.8[ab]	168.2[b]	167.9[ab]	167.4[ab]
(*n* = 2511)	(166.9; 167.8)	(167.4; 168.3)	(167.3; 168.4)	(167.7; 168.8)	(167.2; 168.7)	(166.8; 168.1)
Height SD score						
Mean 1 (95% CI)	0.07[a]	0.13[ab]	0.14[ab]	0.20[b]	0.13[ab]	0.08[ab]
(*n* = 2681)	(–0.00; 0.14)	(0.05; 0.21)	(0.05; 0.23)	(0.12; 0.29)	(0.02; 0.25)	(–0.02; 0.18)
Mean 2 (95% CI)	–0.07[a]	0.02[ab]	0.02[ab]	0.08[b]	0.02[ab]	–0.05[ab]
(*n* = 2511)	(–0.13; –0.01)	(–0.05; 0.09)	(–0.07; 0.10)	(–0.00; 0.16)	(–0.09; 0.14)	(–0.14; 0.04)

*Mean 1 adjusted for baseline body mass index (BMI), waist or height measure. †Mean 2 adjusted for baseline BMI, waist or height measure plus age, gender, deprivation, ethnicity, pubertal stage, diet and exercise behaviour. ‡Means not sharing letters with each other are significantly different at the $P < 0.05$ level.

and reduced the inconsistent association between self-reported smoking and waist circumference still further. As differences were small, data have been presented for the non-transformed values for ease of interpretation.

The robustness of our findings was checked by repeating the mixed-model analysis including BMI, waist and height data from all available years on all available students. The results remained similar to those reported above, with significant smoking status by study year interactions again showing the yearly increase in BMI and BMI SD score among regular smokers to be lower than that of other smoking groups and never smokers ($P < 0.0001$). These findings were also replicated using cotinine values ($P < 0.0001$). The results for waist circumference also showed a clear effect of smoking, with regular smokers showing lower gains in waist circumference and waist SD score over time than other students ($P < 0.0001$, $P < 0.007$). The association between cotinine-defined smoking and waist circumference and waist SD score was also significant ($P = 0.009$, $P = 0.022$). No associations were found involving height and smoking status.

DISCUSSION

We found that students who were regular smokers at age 15–16 had a lower BMI than other students, controlling for ethnicity, socio-economic deprivation, pubertal status, self-reported diet and exercise and BMI at age 11–12. There was no evidence for an interaction by gender. Although the findings were less consistent across all models and dependence variables, regular smoking at age 15–16 was also associated with lower waist circumference. We did not detect a clear and consistent relationship between regular smoking and height.

While there were no significant differences in anthropometric measures between smoking groups at either age 11–12 or age 15–16 cross-sectionally, a finding consistent with past cross-sectional studies which have found teenage smokers to weigh the same or more than non-smokers [12], our longitudinal findings support the more recent work of Stice & Martinez [18], who found weight, height and BMI growth to be reduced in persistent female smokers over a 1-year period. However, unlike Stice & Martinez, we did not observe an association between smoking and height. The current study extends these findings by showing an effect of smoking on adiposity among boys as well as girls, examining BMI and height change over a longer period and including waist circumference as a more direct index of adiposity.

The effect sizes observed in relation to weight and waist circumference were relatively small. We do not know how visible or salient such differences would be to adolescents themselves. However, given that the raw BMI and waist measurements between the smokers and non-smokers did not differ, the differences in weight gain between smokers and non-smokers is unlikely to be apparent.

Previous findings that adolescents believe that smoking will help them to stay slim, and that weight concern and smoking behaviour tend to be associated, have led to recommendations that smoking prevention approaches among adolescents need to aim to alter perceptions of smoking as an effective weight control tool [27]. This study suggests a need for prevention strategies with alternative recommendations for healthy weight maintenance. It should also be noted that smoking cessation in adults is associated with a weight gain of between 4.8 kg (10.6 lb) and 5.9 kg (13.0 lb) [28]. The association between smoking and weight found here is therefore likely to be considerably smaller than the weight gain that will be experienced by adolescents who quit smoking after reaching adulthood.

Our study has a number of strengths. These include the use of age and gender-specific BMI SD scores to control for the natural increase in BMI over time; the inclusion of waist circumference, which had not been assessed previously longitudinally; the 4-year duration of the study and the use of objective height and weight data, as well as of nicotine intake. The inevitable attrition that occurs with all longitudinal studies is an obvious limitation. To reduce the impact of this, and to ensure that the greatest number of regular smokers were included, analyses were limited to baseline data at year 7 and final year data at year 11. However, this meant that a more detailed examination of the effect of increasing duration and intensity of smoking on weight change was not possible. In addition, those excluded were disproportionately non-white, deprived, physically mature and more likely to both currently smoke and have a larger BMI and waist circumference. This obviously has the potential to skew the data and although it would not generate an association between smoking and weight that was not present in the underlying population, it could bias the estimate of effect size. However, the fact that the confirmatory model using all BMI, waist and height data from students where this was available yielded a similar result suggests that the extent of bias is likely to be small.

It should also be noted that the original sample was not designed to be representative of the general population but rather to be ethnically and socio-economically diverse, a characteristic maintained in this reduced sample. Finally, as with all correlational analyses, the finding that smoking is associated with a reduced weight gain relative to the trajectory in non-smokers could be due to confounding variables that have not been measured or measured with sufficient precision.

In conclusion, this study found a smaller BMI at age 15–16, adjusted for baseline BMI, among regular smokers compared with other students. Smoking at age 15–16 also appeared to be associated with a reduced waist circumference, but we could detect no consistent associations between smoking and height. Whether these differences are apparent to adolescents themselves is uncertain, but there can be little doubt that the adverse effects of smoking greatly outweigh any effects of lower adiposity [29,30]. Adolescents who are concerned about weight should be advised strongly that smoking is not an appropriate solution and made aware of healthier approaches to weight control.

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Declarations of interest

Robert West undertakes research and consultancy for developers and manufacturers of smoking cessation treatments such as nicotine replacement products. No other authors have any conflicts of interest.

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