Published in final edited form as:

Am J Hum Biol. 2011 September ; 23(5): 635–641. doi:10.1002/ajhb.21191.

Growing into obesity: Patterns of height growth in those who become normal weight, overweight or obese as young adults

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Abstract

Objective—To study whether patterns of height growth differ by adult obesity status, and determine the contribution of subcutaneous fatness as an explanatory variable for any differences.

Study design—A multicenter, prospective longitudinal cohort assessed in 3rd grade (8.8 years), 5th grade (11.1 years), 8th grade (14.1 years) and 12th grade (18.3 years). Exposures were young adult obesity status classified by CDC adult BMI categories at 12th grade. Skinfolts were measured in 3rd, 5th and 8th grades. Outcome was mean height (cm) at the four measurements using repeated-measures ANCOVA for young adult obesity status, and height increments between grades by adult obesity status in sequential models including initial height and, secondarily, initial skinfolts.

Results—Adjusted for age, and race/ethnicity, young adult obesity status explained a small, but statistically significant amount of height growth among both females and males within each of the three intervals. Compared with normal weight young adults, overweight or obese young adults stood taller in childhood, but had relatively less growth in height throughout the teenage years. There was no association between adult height and weight status. Skinfolts explained only a small amount of the height patterns in the three weight groups.

Conclusion—Childhood and adolescent height growth patterns differ between those who become young adults who are normal weight and those who become overweight or obese. Since differences in fatness explain only a small amount of these height growth patterns, research is needed to identify other determinants.

Keywords

Child obesity; adult obesity; height; skinfolts; longitudinal

Obesity and height are generally unassociated in adults. However, in children, previous research consistently finds a positive association between obesity and height (Bruch, 1939; Freedman et al., 2004a; Freedman et al., 2004b; Stovitz et al., 2008). Longitudinal studies in generally well-nourished populations such as the U.S. and Sweden have found greater child height, particularly early childhood height, to be associated with adult obesity (Freedman et

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None of the authors have any conflicts of interests.

al., 2002; Freedman et al., 2005; He and Karlberg, 2001; Stovitz et al., 2010). Childhood obesity is associated with earlier pubertal maturation, especially in girls (Aksglaede et al., 2009; Biro et al., 2010; Buyken et al., 2009; Himes et al., 2004; Karlberg, 2002; Must et al., 2005; Sandhu et al., 2006; Wang, 2002), and more advanced pubertal development is, in turn, associated with diminished subsequent growth in height and a greater risk for young adult obesity (De Simone et al., 1995; Freedman et al., 2004a; He and Karlberg, 2001; Mamun et al., 2009; Rzehak and Heinrich, 2006). Thus, it is clear that height growth, even in well-nourished populations, does not occur in isolation from the child's nutritional status and is accelerated by obesity. However, this association generally remains under-recognized by pediatricians and parents who may perceive elevated height in the overweight child as a sign that, with time, the child will "grow out of" their overweight condition. A clearer understanding of the childhood growth characteristics of overweight and obese young adults will help pediatricians assess the risk for future obesity in the child who is relatively tall or short.

The purpose of the current investigation is to better understand the complex relationship of height growth and young adult obesity status. Using a large longitudinal cohort from four distinct areas of the U.S., we will examine differences in height growth between those who were overweight or obese by early adulthood as compared to those who were normal weight. The longitudinal approach allows us to study in detail the magnitude and timing of differences in height growth curves across the adult weight classification groups. Based on past research, we anticipate that those who become overweight or obese as young adults will have been relatively taller in early childhood, and then will have had slower growth in height with advancing age. In this study, we also examine the degree to which differences in height growth can be explained by variation in childhood subcutaneous fat thickness in an attempt to separate the effects of current fatness in childhood from subsequent obesity status as a young adult.

METHODS

Study participants

Participants are a cohort from the Child and Adolescent Trial for Cardiovascular Health (CATCH). CATCH was a multi-center, cluster-randomized field trial designed to evaluate the effectiveness of classroom and environmental interventions encouraging a heart-healthy diet, physical activity, and the avoidance of smoking to reduce cardiovascular risk factors. Four field centers in the United States (University of California at San Diego; University of Minnesota; University of Texas at Austin; and Tulane University, Louisiana) randomized 96 schools to either intervention (14 schools per site, 56 total) or control (10 per site, 40 total). Details of the original study are described elsewhere (Perry et al., 1990).

The study originally assessed 3rd graders ($n = 5,106$) during the fall of 1991. Participants were measured in 5th grade ($n = 3,963$), in 8th grade ($n = 3,679$) and in 12th grade ($n = 2,909$), during the springtime of the years 1994, 1997 and 2001. Average age was 8.8, 11.1, 14.1 and 18.3 years in grades 3, 5, 8 and 12, respectively ($SD = 0.5$ in all grades). The females were one-tenth of a year younger than the males at each measurement. Drop-outs from the original cohort were those moving out of the area or choosing not to participate in the final survey ($n = 1,968$), and those who did not return consent forms ($n = 229$). Of those evaluated in 12th grade, 101 had missing data in either the 3rd or 12th grade. Data from participants who had height and weight measured at each grade level were used ($n = 2,808$). In the participant data used in these analyses, the intervention and control groups did not differ with respect to weight, height, or skinfolds at baseline or at follow-up and so interventional status was ignored.

Anthropometry

All measurements were taken by trained and certified study examiners. Subjects were measured after removing their shoes, sweaters and outerwear. Standing height was measured twice without shoes to the nearest 0.1 cm using a portable stadiometer (Perspective Enterprises, Inc, Kalamazoo, MI). Weight was measured twice to the nearest 0.1 kg using balance beam scales (Detecto Medic balance scale, Detecto Scales Inc, Brooklyn, NY). The mean of the two measurements were used for analysis. BMI was calculated as weight (kg) divided by height (m) squared. Exact percentiles for weight, height and BMI for age and gender were calculated relative to the CDC 2000 reference growth charts for U.S. children (Kuczmarski et al., 2000). Final weight categories in 12th grade used adult standards, that is, overweight was defined as BMI ≥ 25 but less than 30 kg/m², and obesity was defined as BMI ≥ 30 kg/m². Since only 5.8% of the cohort was underweight by CDC standards as a young adult (BMI < 18.5), and the height growth patterns of these participants was similar to those within the normal weight category, for simplicity, we labeled as “normal weight” all young adults with a BMI < 25 kg/m². Lange skinfold calipers were used in grades 3, 5 and 8 to obtain three consecutive replicate measurements of triceps and subscapular skinfolds. The average of the three triceps and subscapular skinfold measurements, respectively, were converted into percentile values for each using the smoothing parameters in Addo and Himes, 2010 (Addo and Himes, 2010). The percentile values were then averaged for the sum of skinfolds.

Statistical analyses

All analyses are stratified by sex/gender as height and fatness over this age range differ considerably between girls and boys. Descriptive statistics categorized by young adult weight categories (normal, overweight, or obese in Grade 12) were generated. Independence of self-reported ethnicity and young adult weight category was tested by the chi-square statistic. For continuous variables of interest (BMI, height and skinfolds), the mean levels were calculated by young adult weight categories at grade 12 (not available for skinfolds). Differences between weight categories were tested by analysis of variance (ANOVA). For grades 3, 5 and 8 the age- and gender-specific percentile and semi-interquartile range (SIQR) were calculated by young adult weight category. Data is presented as median percentile, and differences tested by non-parametric ANOVA (Kruskal-Wallis test) (Conover, 1999).

Repeated-measures over grade level height by adult weight categories (RM-ANCOVA) was used to generate mean heights (adjusted for age within grade) at each grade, for those who became normal weight, overweight or obese in grade 12; differences in height compared to those of normal weight category in grade 12 were plotted by grade for the obese and overweight groups. Finally, lagged models of height increments by adult weight-status were examined for the three intervals – from 3rd to 5th grade, 5th to 8th grade, and 8th to 12th grade. A base model adjusted for age and height (at the start of each interval), and race. To assess the added information in the sum of skinfolds, a main effect of interval-starting skinfolds was added to the lagged model, and the interaction of the adult weight-status by the interval-starting skinfolds was tested. Goodness of fit and improvements in fit were evaluated by the coefficients of determination (R^2).

RESULTS

Table 1 presents the crude descriptive data for the 2808 participants, stratified by gender and young adult weight categories. Non-Hispanic whites accounted for 71% of the females (Table 1A) and 77% of the males (Table 1B). There was a moderate amount of ethnic diversity with non-Hispanic blacks making up 12% and Hispanics accounting for 10% of the

entire cohort. As young adults, overall, 13% were “obese” ($\text{BMI} \geq 30$), 22% were overweight ($\text{BMI} \geq 25$ and < 30) and 65% had a $\text{BMI} < 25$. In all grades and for both females and males, the median percentiles for BMI and skinfolds increased progressively across categories of young adult weight categories from normal to overweight to obese.

As seen in Figure 1, after adjustment for age, height growth patterns differed in those who became overweight or obese as young adults compared with those who did not. Among the females, at approximately age 9 years, those who were obese as adults stood approximately 4.5 cm taller than those who were in the normal weight range as adults (Figure 1A). The difference in child height between the obese and normal weight female groups was even greater by age 11 years, at 5.7 cm. Among the females, the positive association between adult obesity status and previous height diminished by age 14 years, whereby there was only a 1.3 cm difference between the participants who were obese and those who were in the normal weight range as adults. For the first three measurement occasions, the mean height of the overweight group was between that of the obese and the normal weight groups. As young adults (approximately 18 years), there was no appreciable association between height and obesity status among the females, $p\text{-value} = 0.08$, without evidence of a linear trend.

Height differences for the males, after adjustment for age, are seen in Figure 1B. At approximately age 9 years, those who became obese or overweight stood approximately 3.5 cm taller than those who had normal weight as an adult. Differences in height were slightly greater by age 11 years, whereby those who became obese were, on average, 4.5 cm taller than the normal weight group. In contrast to the females, large differences in height remained at the 14 year-old measurement, where those who were overweight or obese adults stood approximately 3 cm taller than those who were in the normal range as adults. Between ages 14 and 18 years, the adult normal weight males grew approximately 12 centimeters in height (Data not shown). At the young adult measurement, there was no significant association between height and obesity status among the males ($p = 0.56$).

Tables 2A and 2B show the increment in height growth between the measurement intervals for the females and males, respectively, via successive modeling after adjustment for race and interval starting age and height. For the females, within each of measurement intervals, there was a statistical interaction between the amount of subcutaneous fatness (as measured by skinfolds) and young adult weight status ($p < 0.0001$ for each interval). For the interval between the 3rd and 5th grades, subcutaneous fatness was positively associated with height growth among those who became normal weight adults, and negatively associated with height growth among those who became overweight or obese adults. For the intervals 5th–8th grade and 8th to 12th grade, the pattern reversed. In these two intervals, those who became normal weight adults, had a small negative association between adiposity and height growth, and those who became overweight or obese had a small positive association between adiposity and height growth. For the females, there was very little change in height between the 8th and 12th grade measurements, especially for the obese adult females who grew approximately 1.5 cm over the four-year interval (Data not shown).

Unlike the females, within the males there was no significant interaction between the amount of subcutaneous fatness and young adult weight status. Subcutaneous fatness conferred a somewhat strong effect only during the adolescent period (ages 14.2–18.3 years), whereby a 1 cm difference in skinfolds was positively associated with a 0.74 ($\text{SE}=0.15$) cm growth differential.

DISCUSSION

There is an epidemic of obesity in the U.S. and much of the world (Han et al., 2010; Ogden et al., 2010; Wang and Lobstein, 2006). The majority of overweight youth become overweight adults (Whitlock et al., 2005), with overweight children who are also tall, having a significantly higher risk of becoming overweight adults compared with overweight children who are shorter (Freedman et al., 2002; Stovitz et al., 2010). Previous longitudinal studies have shown that individual height growth patterns are partially dependent upon concurrent fatness (De Simone et al., 1995; Freedman et al., 2004a; He and Karlberg, 2001). Our study is novel in finding that future obesity status, is a significant determinant of height growth patterns in both genders, even after adjusting for the height at the beginning of each measurement interval. We found that at around 9 and 11 years of age, large differences in height existed between young adult females and males who were obese compared with those who were normal weight. The magnitude of these height differences decreased precipitously after age 11 years in the females, and after age 14 years in the males. The waning height advantage with age resulted in similar heights in obese, overweight and normal weight young adults by age 18. The findings suggest that the faster height growth in children that become obese is indicative of accelerated physical maturation, although information on pubertal or skeletal development was not available in the present study.

Many interpret the gender specific stature-for-age reference charts (e.g. the United States' CDC 2000 (Kuczmarski et al., 2000)) to suggest that individual height growth patterns are independent of body weight and obesity risk. However, this is clearly not the case. The fact that the growth reference charts are not meant to predict individual growth patterns was specified by the authors of the U.S. reference charts. The data used to form the reference charts were from serial cross-sectional measurements, and the authors stated that "these charts more appropriately may be considered size charts." (Kuczmarski et al., 2000) Studies dating back to the early part of the 20th century have noted that obese children tend to stand taller than their non-obese peers (Bruch, 1939). Longitudinal studies suggest that the increased stature in obese youth is associated with advanced skeletal maturation, as there is less subsequent growth in height through the adolescent years (De Simone et al., 1995; Freedman et al., 2004a; He and Karlberg, 2001; Mamun et al., 2009; Rzehak and Heinrich, 2006). The purpose of this study was to better understand the height growth patterns of those who become overweight or obese in contrast with those who become normal weight adults.

Using data from the 2,808 participants from the CATCH trial who had measurements in both 3rd grade and 12th grade, we examined how much of the different growth patterns could be explained by differences in subcutaneous fatness (as measured by triceps and subscapular skinfolds). Using a lag-model (interval-starting subcutaneous fatness in predicting interval height change), we found that subcutaneous fatness added only a small amount of information to the determination of height growth patterns of the groups. There were complex gender- and age-specific variations in the height-obesity relationships. Among the females, there was a statistically significant interaction between skinfold thickness and adult overweight categories within each measurement interval. In the earliest interval, between grades 3 and 5, for those who became normal weight as young adults, greater subcutaneous fat was positively associated with faster growth in height. In contrast, for those who became overweight or obese adults, height growth was slower in those with larger amounts of subcutaneous fatness. After 5th grade, the pattern reversed, whereby the normal weight adults had a statistically significant negative association between fatness and height growth. In contrast, for those who became obese, fatness had no significant effect on height growth after 5th grade (approximately 11 years of age). For girls, height velocity increases approximately two years prior to menarche (Karlberg, 2002). Menarchal age at the time of our study, the mid-1990's, averaged approximately 12.5 years (Anderson and Must, 2005),

and menarche is known to present earlier in obese females (Aksglaede et al., 2009; Biro et al., 2010; Buyken et al., 2009; Himes et al., 2004; Must et al., 2005; Sandhu et al., 2006; Wang, 2002).

Among the males, there was no statistically significant interaction between skinfold thickness and adult weight category in their relationship with height growth. The main effects analysis showed only small effects of fatness on height increments until the interval between 8th and 12th grades in which all young adult weight groups had a positive association between fatness and greater height velocity. For example, between the 3rd and 5th grade measurements the coefficient of determination for interval height growth was 21.1% prior (with knowledge of age, race/ethnicity, interval starting height and adult weight category) and 21.5% after the addition of skinfolds to the model. The association between fatness and puberty is known to be weaker in boys as compared with girls (Buyken et al., 2009; Wang, 2002). Any study of the relationship of fatness and puberty in males is complicated by the fact that puberty leads to a relative decrease in the ratio of fat mass to lean mass. Growth in males often occurs beyond the age of 18 years (Roche and Davila, 1972), and we hypothesize that the males with relatively lower amounts of fatness had residual height growth remaining at our study's end.

Previous studies have found that the positive relationship between obesity and height starts in early childhood, i.e. well before the first measurements in our study (De Simone et al., 1995; Freedman et al., 2002; He and Karlberg, 2001; Himes, 1999). We found that prior to 3rd grade, the obese young adults had already experienced meaningful accelerated linear growth which impacted subsequent growth. Little research has been conducted on the origins of these height growth differences in infancy. Studies of prenatal and early postnatal recumbent length and weight growth may be useful in the early identification of children at risk for obesity. In 1995, De Simone et al reported research using hand radiographs as a direct measure of bone maturation and found obesity to be positively associated with skeletal maturation throughout childhood and into puberty (De Simone et al., 1995). Assessment of the risk for adult obesity may be improved through further studies assessing the temporal relationships between height growth, skeletal maturation, obesity development and pubertal onset.

Our study had limitations. Only 55% (2808 of 5106) of the original cohort was available for the 12th grade measurements and thus used for this study. Compared with the original cohort, those remaining in the study were generally similar, but slightly lighter, and more likely to be female and Non-Hispanic White. Skinfolds are an imperfect measurement of adiposity, and skinfolds were not measured in the 12th grade. Pubertal stages were not measured. We assumed that 12th grade height was the adult height of the subjects. However, height growth may have been incomplete in some subjects, especially in the thinner males (Roche and Davila, 1972).

The study also had important strengths. We believe this study to be unique in that it evaluated the longitudinal interrelationships of height and obesity from a retrospective/etiologic perspective. By stratifying on adult weight category, we were able to determine that obese and overweight young adults had differential height growth patterns compared with adults who were in the normal weight range. We are unaware of any study of the U.S. population with a larger sample measured at ages that generally encompasses the entire adolescent growth spurt.

In conclusion, our study of a large longitudinal cohort with serial measurements throughout late childhood and adolescence found that height growth patterns differed in young adults who were normal weight compared with those who were overweight or obese. On average,

those who were overweight or obese adults were relatively taller in childhood and then had comparatively less height growth over their teenage years. Researchers and clinicians should recognize that children on a course toward adult obesity are likely to exhibit a height advantage in the pre-teenage years, but with subsequently faster height deceleration in later adolescence. Concurrent adiposity explained only a small amount of the height growth patterns between different weight category groups. Research is needed to identify other determinants for the differences in height growth patterns.

Acknowledgments

Grant information: This work was supported by a career research training grant (for SDS) from the NIH/NCRR (5K12-RR023247-04), funds from the NCI Centers for Transdisciplinary Research on Energetics and Cancer (U54CA116849), and the University of Minnesota Obesity Prevention Center. The opinions or assertions contained herein are the private ones of the authors and are not considered as reflecting the views of the National Institutes of Health.

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Figure 1.
Average differences in height between the obese and the overweight adults compared with the normal weight adults, adjusted for age

Table 1A

Description of the CATCH sample by young adult weight status - (A) Females

Variable of interest	Normalwt gr12 n=944	Overwt gr.12 n=293	Obese gr.12 n=196	Statistical testing
Ethnicity				$\chi^2(6) = 53$
Non-Hispanic white n (%)	708 (75%)	190 (65%)	115 (59%)	p<0.001
Non-hispanic black n (%)	94 (10%)	48 (16%)	52 (27%)	
Hispanic/Latina n (%)	97 (10%)	46 (16%)	25 (13%)	
Other ethnicity n (%)	45 (5%)	9 (3%)	4 (2%)	
Body Mass Index				F-stat(2)
-BMI (kg/m ²) as young adults (Mean, SD)	21.3 (2.1)	26.9 (1.4)	35.2 (4.6)	p<0.001
-BMI in childhood and adolescence				
Grade 3: Median percentile (SIQR [*])	0.46 (0.20)	0.80 (0.14)	0.95 (0.05)	p<0.001
Grade 5: Median percentile (SIQR)	0.46 (0.23)	0.84 (0.10)	0.96 (0.03)	p<0.001
Grade 8: Median percentile (SIQR)	0.54 (0.19)	0.88 (0.06)	0.97 (0.03)	p<0.001
Height				
Height in cm as young adults (Mean, SD)	164.3 (6.5)	163.3 (6.5)	164.3 (6.5)	p=0.080
Height in childhood and adolescence				
Grade 3: Median percentile (SIQR)	0.50 (0.23)	0.59 (0.21)	0.74 (0.20)	p<0.001
Grade 5: Median percentile (SIQR)	0.56 (0.24)	0.72 (0.22)	0.83 (0.18)	p<0.001
Grade 8: Median percentile (SIQR)	0.55 (0.24)	0.55 (0.24)	0.64 (0.26)	p=0.057
Sum Skinfolts in mm				
Grade 3: Median percentile (SIQR)	0.49 (0.19)	0.80 (0.15)	0.94 (0.08)	p<0.001
Grade 5: Median percentile (SIQR)	0.48 (0.20)	0.82 (0.14)	0.93 (0.05)	p<0.001
Grade 8: Median percentile (SIQR)	0.49 (0.17)	0.80 (0.11)	0.92 (0.06)	p<0.001

Mean ages in Grade 3, 5, and 8, and as young adults (grade 12) were 8.7, 11.1, 14.1, 18.2 years (SD = 0.5 years). Young adult overweight is defined as $25 \leq \text{BMI} < 30$. Obesity is defined as a $\text{BMI} \geq 30 \text{ kg/m}^2$.

Z-scores for sum of skinfolts derived from smoothing parameters in Addo and Himes, 2010. See methods.

* SIQR = Semi-interquartile range.

Table 1B

Description of the CATCH sample by young adult weight status - (B)Males

Variable of interest	Normalwt gr12 n=865	Overwt gr.12 n=338	Obese gr.12 n=172	Statistical testing
Ethnicity				$\chi^2(6) = 53$
Non-Hispanic white n (%)	699 (81%)	251 (74%)	112 (65%)	p<0.001
Non-hispanic black n (%)	80 (9%)	33 (10%)	28 (16%)	
Hispanic/Latino n (%)	58 (7%)	39 (12%)	25 (15%)	
Other ethnicity n (%)	28 (3%)	15 (4%)	7 (4%)	
Body Mass Index				F-stat(2)
BMI (kg/m ²) as young adults (Mean, SD)	21.63 (1.95)	27.16 (1.45)	34.75 (4.68)	
BMI in childhood and adolescence				
Grade 3: Median percentile (SIQR [*])	0.50 (0.19)	0.84 (0.10)	0.95 (0.06)	p<0.0001
Grade 5: Median percentile (SIQR)	0.50 (0.21)	0.88 (0.10)	0.97 (0.03)	p<0.0001
Grade 8: Median percentile (SIQR)	0.52 (0.20)	0.87 (0.08)	0.98 (0.02)	p<0.0001
Height				
Height in cm as young adults (Mean, SD)	177.1 (6.9)	177.4 (7.1)	177.7 (7.2)	p=0.564
-Height in childhood and adolescence				
Grade 3: Median percentile (SIQR)	0.50 (0.23)	0.63 (0.22)	0.70 (0.24)	p<0.001
Grade 5: Median percentile (SIQR)	0.53 (0.23)	0.68 (0.22)	0.75 (0.20)	p<0.001
Grade 8: Median percentile (SIQR)	0.53 (0.25)	0.70 (0.22)	0.68 (0.23)	P<0.001
Sum Skinfololds in mm				
Grade 3: Median percentile (SIQR)	0.53 (0.18)	0.80 (0.16)	0.95 (0.08)	p<0.001
Grade 5: Median percentile (SIQR)	0.57 (0.20)	0.88 (0.20)	0.96 (0.04)	p<0.001
Grade 8: Median percentile (SIQR)	0.51 (0.17)	0.82 (0.15)	0.95 (0.03)	p<0.001

Mean ages in Grade 3, 5, and 8, and as young adults (grade 12) were 8.8, 11.2, 14.2, 18.3 years (SD = 0.5 years). Young adult overweight is defined as $25 \leq \text{BMI} < 30$. Obesity is defined as a $\text{BMI} \geq 30 \text{ kg/m}^2$.

Z-scores for sum of skinfololds derived from smoothing parameters in Addo and Himes, 2010. See methods.

* SIQR = Semi-interquartile range.

Table 2A

Females. Increment in height (cm) between measurement intervals giving model R^2 , parameter estimates and p-values:

- A. base model is adjusted for age, race, and initial height^a
- B. base model with addition of adult weight status
- C. model B with addition of 1 cm difference in skinfold thickness at the initial grade as main effect (on left) and
- D. as interaction of skinfold thickness with adult weight status

Interval (mean age, years)	A Base			B-Base model Plus Adult Weight status			C-Plus skinfold thickness (units 10mm)			D-Interaction of skinfold thickness and adult weight status			
	R^2 (%)	Difference in height increment ^b		p-value(2 df)	R^2 (%)	Difference in Ht^c per 10mm diff. in skinfolds (SE)	p-value (1 df)	R^2 (%)	Adult wt. status	Difference in Ht^d (SE)	p-value (1 df)	R^2 (%)	interaction p-value
8.7 – 11.1	16.7	Obese +0.28	Overweight +0.55	0.024	17.2	-0.12 (0.10)	0.223	17.3	Obese	-0.54 (0.17)	0.002		
			Normal ref.						Overweight	-0.36 (0.19)	0.059	18.4	<0.0001
									Normal	+0.35 (0.15)	0.022		
11.1 – 14.1	37.1	Obese -1.90	Overweight -1.02	<0.0001	38.6	-0.06(0.12)	0.652	38.6	Obese	+0.77 (0.24)	0.002		
			Normal ref.						Overweight	+0.18 (0.23)	0.430	39.8	<0.0001
									Normal	-0.58 (0.17)	0.001		
14.1 – 18.2	8.8	Obese -1.25	Overweight -1.20	<0.0001	12.5	-0.24 (0.08)	0.002	13.2	Obese	+0.18 (0.14)	0.215		
			Normal ref.						Overweight	+0.02 (0.15)	0.896	14.8	<0.0001
									Normal	-0.64 (0.11)	<0.0001		

^a Average initial heights at ages 8.7, 11.1, 14.1, and 18.2 years are 132, 147, and 161cm, respectively.

^b Difference in Ht (cm) for two girls with the same age, race and initial height but with eventually differing young adult weight status.

^c Difference in Ht (cm) for two girls with the same age, race, initial height and young adult weight status, for 10mm difference in sum of skinfolds at the earlier grade.

^d Difference in Ht (cm) for two girls with the same age, race, initial height and young adult weight status as indicated, for 10mm difference in sum of skinfolds at the earlier grade.

Table 2B

Males. Increment in height (cm) between measurement intervals giving model R^2 , parameter estimates and p-values:

- A.** base model is adjusted for age, race, and initial height^a
- B.** base model with addition of adult weight status
- C.** model B with addition of 1 cm difference in skinfold thickness at the initial grade as main effect (on left) and
- D.** as interaction of skinfold thickness with adult weight status

A Base		B-Base model Plus Adult Weight status			C-Plus skinfold thickness (units 10mm)			D-Interaction of skinfold thickness and adult weight status				
Interval (Mean ages, years)	R ² (%)	Difference in height increment ^b	p-value (2 df)	R ² (%)	Difference in Ht ^c per 10mm diff. in skinfolds (SE)	p-value (1 df)	R ² (%)	Adult wt. status	Difference in Ht ^d (SE)	p-value (1 df)	R ² (%)	interaction p-value
8.8 – 11.2	19.2	Obese +0.77						Obese	+0.01 (0.11)	0.923		
		Overweight +0.62	<.0001	21.1	+0.17(0.07)	0.021	21.5	Overweight	+0.25 (0.14)	0.059	21.7	0.140
		Normal ref.						Normal	+0.34 (0.14)	0.074		
11.2 – 14.2	5.3	Obese –1.72						Obese	–0.16 (0.24)	0.465		
		Overweight +0.05	<.0001	6.9	–0.23(0.13)	0.062	7.2	Overweight	–0.59 (0.21)	0.006	7.6	0.094
		Normal ref.						Normal	+0.03 (0.20)	0.879		
14.1 – 18.3	37.5	Obese –0.60						Obese	+0.64 (0.29)	0.028		
		Overweightt –1.30	0.0015	38.2	+0.74 (0.15)	<.0001	39.3	Overweight	+0.67 (0.26)	0.010	39.3	0.794
		Normal ref.						Normal	+0.87 (0.24)	0.0004		

^a Average initial heights at ages 8.8, 11.2, 14.2 and 18.3 years are 133, 146, and 166cm, respectively.

^b Difference in Ht (cm) for two boys with the same age, race and initial height but with eventually differing young adult weight status.

^c Difference in Ht (cm) for two boys with the same age, race, initial height and young adult weight status, for 10mm difference in sum of skinfolds at the earlier grade.

^d Difference in Ht (cm) for two boys with the same age, race, initial height and young adult weight status as indicated, for 10mm difference in sum of skinfolds at the earlier grade.