Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: the Amsterdam Growth and Health Longitudinal Study[1–3]

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ABSTRACT

Background: Body mass index (BMI) during adolescence is predictive of BMI at adult age. However, BMI cannot distinguish between lean and fat body mass. Skinfold thickness may be a better predictor of body fatness.

Objective: The objective of this study was to evaluate the relations between BMI and skinfold thickness during adolescence and body fatness during adulthood.

Design: We included 168 men and 182 women from the Amsterdam Growth and Health Longitudinal Study, a prospective study that conducted 8 measurements of BMI and skinfold thickness between 1976 and 2000. BMI and skinfold thickness during adolescence were analyzed in relation to adult body fatness measured at a mean age of 37 y with dual-energy X-ray absorptiometry.

Results: None of the boys and 1.7% of the girls were overweight at baseline, whereas the prevalence of high body fatness during adulthood was 29% in men and 32% in women. At the ages of 12–16 y, skinfold thickness was more strongly associated with adult body fatness than was BMI. Age-specific relative risks for a high level of adult body fatness varied between 2.3 and 4.0 in boys and between 2.1 and 4.3 in girls in the highest versus the lowest tertile of the sum of 4 skinfold thicknesses. For the highest tertile of BMI, the relative risk varied between 0.8 and 2.1 in boys and between 1.3 and 1.8 in girls.

Conclusion: Skinfold thickness during adolescence is a better predictor of high body fatness during adulthood than is BMI during adolescence. *Am J Clin Nutr* 2007;85:1533–9.

KEY WORDS Adolescents, adults, body fatness, body mass index, cohort study, dual-energy X-ray absorptiometry, longitudinal study, skinfold thickness

INTRODUCTION

Overweight during adolescence is a risk factor for overweight in adulthood (1–8) and for several chronic diseases, such as cardiovascular disease (4, 6, 7), type 2 diabetes (4), certain forms of cancer (9), and adult mortality (9, 10). Over the past decades, the mean body mass index (BMI) and the prevalences of overweight and obesity in adolescents have increased dramatically (11, 12). The prevention of excessive weight gain during adolescence is crucial for the reduction of the pandemic of overweight and its related consequences.

Adolescence appears to be a critical period for the development of obesity (13). Still, little is known about the identification of adolescents who are at increased risk of becoming overweight or obese at an adult age, and it is uncertain which measures should be used to identify adolescents at high risk of adult obesity. The widely used definitions of overweight and obesity in adolescents are based on age-specific BMI (in kg/m^2) cutoff points for overweight and obesity that correspond, cross-sectionally, with overweight (BMI ≥ 25) and obesity (BMI ≥ 30) at age 18 y (14).

Several studies have shown tracking of overweight from adolescence to adulthood (2, 6–8, 15). Overweight in these studies was invariably defined by BMI levels. Obesity, however, is defined as an excess of body fat, and it is the amount of this fatness that is associated with morbidities (16), more strongly so than BMI (17). Therefore, the assessment of obesity should ideally be based on measurement of body fatness (18, 19). Because BMI does not distinguish between fat mass and lean body mass (16, 20), a high tracking of BMI from adolescence to adulthood can also represent a high tracking of body build rather than fatness (21). Skinfold thickness (ie, a proxy for subcutaneous fat) is likely to be a better alternative for determining body fatness in children and adolescents (22–25) and for monitoring obesity in children (18).

In the present longitudinal study, we will answer the following research questions: *1*) How has BMI and the sum of 4 skinfold thicknesses (S4SF) developed during and since adolescence in adults with high body fatness and in adults with lower body fatness?

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and 2) Can high body fatness at an adult age be better predicted from BMI or from skinfold thickness during adolescence?

SUBJECTS AND METHODS

Amsterdam Growth and Health Longitudinal Study

The Amsterdam Growth and Health Longitudinal Study (AGAHLS) is an observational, longitudinal study with a total inclusion of 698 subjects. The initial goal of the AGAHLS was to describe the natural development of growth, health, and the lifestyle of adolescents and to investigate longitudinal relations between biological and lifestyle variables (26–28). The study started in 1976 with boys and girls (mean age: 13 y) from the first and second form from 2 secondary schools in the Netherlands: one in Amsterdam and one in Purmerend. Informed consent was obtained from the children and their parents, and all subjects agreed to participate in the study. The AGAHLS was approved by the Medical Ethical Committee of the VU University Medical Center in Amsterdam, Netherlands. The most recent measurement took place in the year 2000 when the subjects' mean age was 37 y. In the adolescent period (mean ages: 13–16 y), 4 annual measurements took place in autumn, followed by measurements at mean ages of 22, 28, 33, and 37 y in the spring. Pupils from the school in Amsterdam were invited for all 8 measurements. Pupils from the school in Purmerend were not invited for the measurements at mean ages of 22 and 28 y. At each measurement, anthropometric (body height, body weight, and skinfold thickness) variables were assessed. During the last examination, all participants were invited for a body-composition measurement by dual-energy X-ray absorptiometry (DXA).

Inclusion

For the present study, only participants who underwent a DXA scan in the year 2000 ($n = 355$) were eligible for inclusion, because we used this percentage body fat (PBF) measurement as our central outcome variable. Subjects who suffered from chronic diseases ($n = 5$) were excluded. Women who reported being pregnant during the measurement in 2000 underwent no DXA scan and, therefore, were not included in the present study. If women had reported being pregnant during a previous measurement, the data from that particular measurement were excluded from the analyses. In total, 168 men and 182 women were included in the present study, from whom data for 2–8 (mean: 6.1) measurements were available.

Anthropometric measures

At each measurement, body height [with a wall-mounted stadiometer (Holtain, Crymych, United Kingdom), to the nearest 0.1 cm], body weight [with a spring balance (van Vucht, Amsterdam, Netherlands), to the nearest 0.1 kg], and S4SF [biceps, triceps, subscapula, and suprailiac to the nearest 0.1 mm with a Harpenden caliper (Holtain)] were assessed according to standard procedures (29). BMI was calculated as body weight (kg) divided by body height squared (m^2). The assessment of overweight during adolescence was based on BMI levels as recommended by the International Obesity Task Force (IOTF) (14). Overweight at an adult age was defined as a BMI $\geq$ 25 (30). S4SF was calculated and expressed in mm. A whole-body DXA scanner (Hologic QDR-2000, software version V5.67A; Hologic Inc, Waltham, MA) was used to assess PBF at the mean age of 37 y. The PBF variable was dichotomized: participants were classified as having high body fatness if their PBF was equal to or exceeded 25% for men and 35% for women. We chose these particular cutoff values for high body fatness because they are simple and within the ranges proposed in earlier publications on this topic (31–33). For clarity, the term *overweight* is used when referring to BMI level, and the terms high and low body fatness when referring to the PBF measured by DXA.

Analyses

The development of BMI and S4SF from mean age 13 to 37 y was calculated for the group of subjects with high and low body fatness at an adult age by using the generalized estimating equations. This method adjusts for the correlation between repeated observations taken in the same subject and has the advantage of handling longitudinal data of varying numbers of subjects and observations unequally spaced in time. In the generalized estimating equations analyses, an exchangeable correlation structure was assumed, and analyses were adjusted for age. To estimate the development of each variable investigated from mean age 13 to 37 y, time was treated as a categorical variable, and the results were plotted. To investigate whether the development of BMI and of the S4SF was different for men and women between adolescence and adulthood and between groups with a high and a lower PBF, we tested the interaction of age and sex and of age and PBF group in a longitudinal regression model. Additionally, at the mean age of 37 y, correlations were calculated between BMI, S4SF, and (the continuous) PBF. Finally, the absolute and relative risk of having high body fatness at an adult age was calculated for age- and sex-specific tertiles of BMI, S4SF, and separate skinfold thicknesses (biceps, triceps, subscapula, and suprailiac) at calendar ages 12–16 y. To analyze whether the relative risks, based on BMI and S4SF tertiles during adolescence, of becoming an adult with high body fatness varied with age during adolescence, we tested the interactions of BMI and age and S4SF and age in a logistic regression analysis. All analyses were performed for men and women separately with the use of SAS version 9.1 (SAS Institute Inc, Cary, NC).

RESULTS

None of the boys and 3 of the girls (1.7%) were overweight on the basis of current international BMI cutoff points when first measured at the mean age of 13 y **Table 1**. At the last follow-up measurement, at the mean age of 37 y, 41.7% of the men and 23.6% of the women had a BMI $\geq$ 25, and 29.2% of the men had a PBF $\geq$ 25% and 32.4% of the women had a PBF $\geq$ 35%.

The interactions of age and sex on the development of BMI and S4SF were highly statistically significant ($P < 0.001$), which indicated that the increase in both BMI and S4SF from adolescence to adulthood is steeper in men than in women. After stratification for sex, the increase in BMI and S4SF from adolescence to adulthood was higher in subjects with a high PBF than in subjects with a lower PBF at an adult age (P for interaction $<$ 0.001) in both men and women.

The longitudinal development of BMI and S4SF in men and women from mean age 13 to 37 y is shown in **Figure 1**. The mean BMI of men and women who were classified as having high body fatness at a mean age 37 y was higher than the mean BMI of the men and women with lower body fatness at the mean age of 37 y, at each year of measurement. Also, at each year of measurement,

TABLE 1
General characteristics of the study population[1]

	Men	Women	*P* for difference[2]
Baseline, 1976			
n	163	172	
Age (y)	12.9 ± 0.6[3]	12.9 ± 0.6	0.77
BMI (kg/m^2)	17.0 ± 1.3	17.7 ± 2.0	< 0.01
Overweight (%)[4]	0.0	1.7	
S4SF (mm)	26.9 ± 8.6	36.3 ± 12.5	< 0.01
Last follow-up, 2000			
n	168	182	
Age (y)	36.5 ± 0.6	36.6 ± 0.6	0.47
BMI (kg/m^2)	24.7 ± 2.8	23.4 ± 3.2	< 0.01
Overweight (%)[4]	41.7	23.6	
S4SF (mm)	47.2 ± 15.8	55.2 ± 19.2	< 0.01
Body fat (%)	21.5 ± 6.3	32.2 ± 6.7	< 0.01
High body fatness (%)[5]	29.2	32.4	

[1] S4SF, sum of 4 skinfold thicknesses.
[2] *t* test.
[3] $\bar{x}$ ± SD (all such values).
[4] The percentage of subjects who were overweight at baseline was derived from age-dependent International Obesity Task Force BMI cutoffs for overweight in adolescents (14). At follow-up, overweight was defined as a BMI ≥25.
[5] Percentage of subjects with high body fatness at the last follow-up: ≥25% for men and ≥35% for women.

the mean S4SF was significantly higher in both the men and women with high body fatness than in the group with lower body fatness at the mean age of 37 y. Differences in BMI and S4SF between the groups became more pronounced with increasing age, which was confirmed by significant interactions ($P <$ 0.0001) of age and PBF group on BMI and S4SF. The group of men with high adult body fatness had a greater increase in body weight (47.3 compared with 38.3 kg), BMI (9.7 compared with 6.9), and S4SF (33.3 compared with 15.0 mm) than did the group of men with lower adult body fatness ($P < 0.0001$). Also, women with a high PBF had a greater increase in body weight (27.2 compared with 20.2 kg), BMI (7.5 compared with 4.8), and S4SF (29.5 compared with 14.1 mm) between the mean ages of 13 and 37 y ($P < 0.0001$) than did women with a lower PBF at an adult age.

In general, the correlations of BMI and skinfold thicknesses at baseline and BMI and skinfold thicknesses at later measurements became lower the longer the follow-up. In men, correlations for body weight decreased from 0.93 between the mean ages of 13 and 14 y to 0.33 between the mean ages of 13 and 37 y. These correlations for BMI and S4SF decreased from 0.89 to 0.40 and from 0.81 to 0.35, respectively. In women, these correlations decreased from 0.94 to 0.44 for body weight, from 0.93 to 0.51 for BMI, and from 0.87 to 0.35 for S4SF. At the mean age of 37 y, correlation coefficients between S4SF and PBF for men (r = 0.84) and women (r = 0.79) were higher than the correlation coefficients between BMI and PBF (r = 0.67 and 0.72 for men and women, respectively).

The risk of having high adult body fatness was not always higher in adolescents with a BMI in the highest tertile than in those with a BMI in the lowest tertile (**Table 2** and **Table 3**). However, in the same adolescents, having an S4SF in the highest tertile was always associated with a higher risk of having high adult body fatness. In women, having a BMI or S4SF in the highest tertile was always associated with a higher risk of becoming an adult with high PBF, but this was not always significant for BMI. The relative risks of the high versus the low S4SF tertile ranged from 2.3 to 4.0 in boys and from 2.1 to 4.3 in girls aged 12–16 y. For BMI, these relative risks were smaller (0.8 to 2.1 in boys and 1.3 to 1.8 in girls) and were not significant most of the time. Relative risks for the high versus the low tertiles of separate skinfold thicknesses were highest for subscapula skinfold thickness in boys (range: 2.4–8.5) and for biceps skinfold thickness in girls (range: 2.3–4.5) (data not shown).

The interaction of BMI tertiles and age was significant ($P <$ 0.10) in boys, which indicated that the relative risks of BMI tertiles with high body fatness at an adult age decreased from age 12 to 16 y. The interactions of BMI and age in girls ($P = 0.90$) and of S4SF and age in both boys ($P = 0.90$) and girls ($P = 0.61$) were not significant.

DISCUSSION

To our knowledge, this is the first longitudinal study that relates adolescent BMI and skinfold thickness to adult body fatness, measured by DXA. Significant differences were observed in mean BMI and S4SF values during adolescence, and in the development of BMI and S4SF into adulthood, between groups of subjects with high and low adult body fatness. Both S4SF and separate skinfold thicknesses for adolescents were better predictors of high body fatness at an adult age than was adolescent BMI.

Many articles have been written on the topic of overweight and obesity in children, adolescents, and adults. In 1997, Power et al (34) presented a review of studies that related adolescent adiposity to adult adiposity. In this review, all studies related adolescent BMI (or weight or relative weight) to adult BMI or adolescent skinfold to adult skinfold thickness. No comparisons have been made between BMI and skinfold thickness in their ability to predict adult adiposity. Also, several studies have been conducted on the same topic since 1997. In contrast with the present study, most of the published studies were *1*) only cross-sectional (35–44), *2*) longitudinal and related childhood or adolescent BMI to adult overweight (based on BMI) (2, 6, 45, 46), or *3*) longitudinal and related childhood or adolescent BMI to adult body fatness (or adiposity) based on either skinfold thickness or DXA (21, 47–50). The overall conclusion of these studies is that adolescent BMI is strongly associated with adiposity (BMI, skinfold thickness, or DXA) measures during adolescence and adulthood. However, to our knowledge, no studies have been published that compared adolescent BMI with adolescent skinfold thickness in relation to adult PBF measured by DXA. We found one study in which both adolescent BMI and skinfold thickness were related to adult adiposity (50). The results showed a slightly stronger association between childhood (and adolescent) triceps skinfold thickness and adult adiposity. However, in that study, adult adiposity was based on skinfold thickness and not on DXA. Although it is not new that skinfold thicknesses relate better to fatness than does BMI, the present study does add new information on this topic. That is, in a longitudinal fashion, the relative risk of becoming an adult with high body fatness based on adolescent BMI was not significant in most of the age- and sex-specific strata. This is in contrast with the mostly significant relative risks based on S4SF in adolescents.

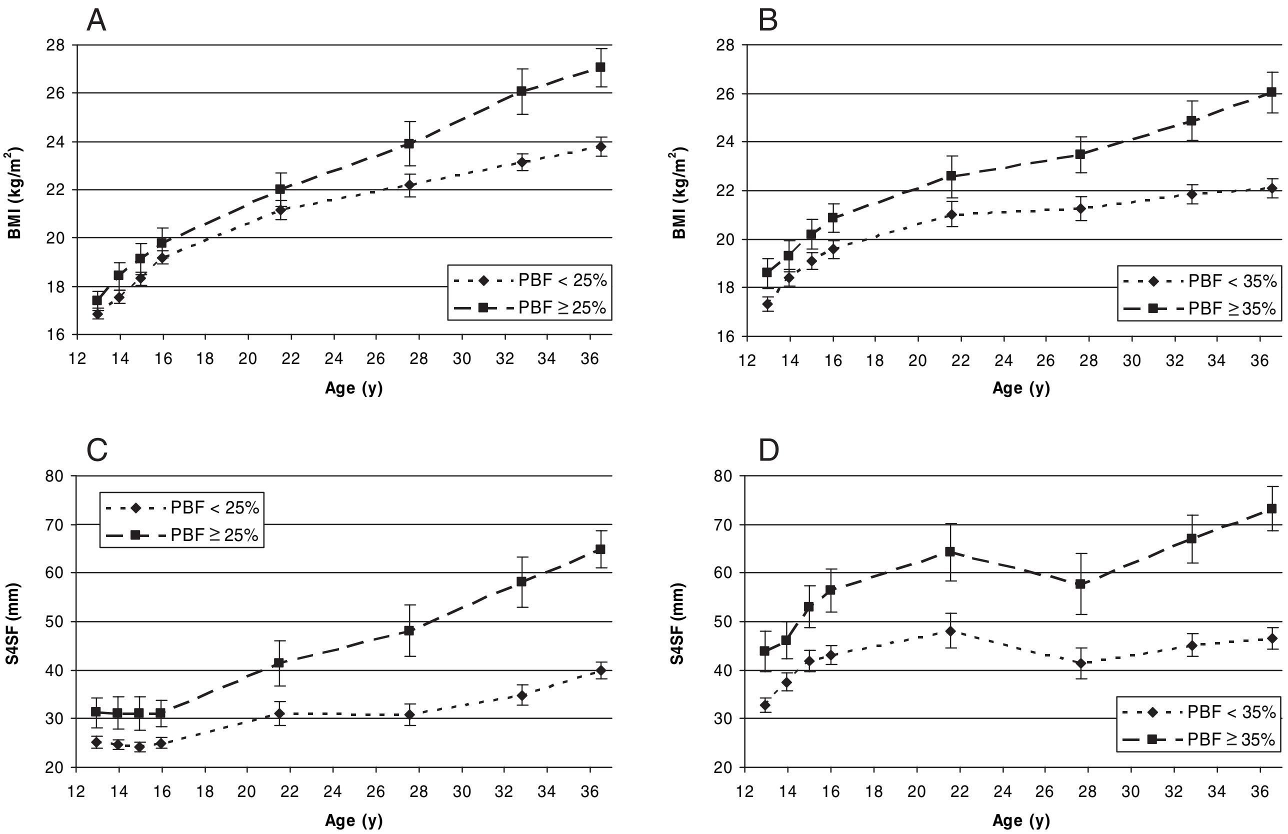

FIGURE 1. Mean longitudinal development of BMI and sum of 4 skinfold thicknesses (S4SF) in men (A and C) and women (B and D) at mean ages ranging from 13 to 37 y, stratified by high and low percentage body fat (PBF) at a mean age of 37 y. Error bars represent 95% confidence limits. The data were derived by using generalized estimating equations and were adjusted for age. The number of subjects at each age is as follows: 13 y (n = 163 M and 172 F), 14 y (n = 134 M and 156 F), 15 y (n = 130 M and 152 F), 16 y (n = 131 M and 154 F), 22 y (n = 64 M and 72 F), 28 y (n = 68 M and 74 F), 33 y (n = 152 M and 173 F), and 37 y (n = 168 M and 182 F). Over all of the years, the proportion of adults with high PBF was 28–31% for men and 30–32% for women, except for years 1985 and 1991 (mean ages: 22 and 28 y), at which time the values were 38% and 37%, respectively. The sex × age × PBF interaction was significant ($P < 0.0001$) for both the development of BMI and S4SF. The age × sex interaction for both variables was also significant ($P < 0.001$). Within each sex, the PBF × age interaction was significant for both variables ($P < 0.001$).

On the basis of our study, it is too early to conclude that the measurement of skinfold thickness should be the standard and the only procedure in clinical practice. Other measures, such as waist circumference, may be useful in predicting health outcomes, and innovative measurements of body fat, such as DXA and 3-dimensional laser techniques, are worthy of study. Ideally, measurements and cutoff points are distinctive in predicting an increased risk of morbidity, disability, or mortality. Such studies in children are rare, because such health outcomes are to be expected decades after baseline measurements are made. Because waist circumference and DXA measurements were introduced only recently for use in adolescents, we will have to wait another few decades for longitudinal relations between these measures during adolescence and PBF at an adult age.

The development of triceps skinfold thickness during adolescence is dependent on sex, but BMI also develops differently in boys and girls during adolescence. This was one of the reasons that we conducted our analyses in boys and girls separately. Of course, on the basis of this fact, one should create guidelines for skinfold thickness cutoff points for boys and girls separately, but the same is true for BMI. Note that it is not our intention to conclude whether a single skinfold thickness measure is a better measure than is another skinfold thickness. Instead, we wanted to demonstrate that even a single skinfold thickness during adolescence is already a better predictor of PBF at an adult age than is BMI during adolescence.

At baseline (mean age: 13 y), none of the boys and only 3 of the girls were classified as overweight (or having a high risk of becoming overweight in adulthood) on the basis of the IOTF cutoffs (14), whereas the prevalence of high body fatness at an adult age in our population was 29% in men and 32% in women. Indeed, all 3 girls who were classified as being overweight at baseline became overweight as adults with a high PBF. However, most of the adults with a high PBF at age 37 y were not classified as overweight at age 13 y on the basis of IOTF BMI cutoff points. This finding agrees with several other studies, which showed a high specificity but a low sensitivity for BMI during adolescence as a predictor of overweight (22, 51, 52).

Sardinha et al (23) conducted a cross-sectional study of the predictability of body fatness (by DXA) from BMI, triceps skinfold thickness, and upper arm girth in adolescent boys and girls. Using receiver operator characteristic analysis, they concluded that, of these 3 measures, triceps skinfold thickness was the best measure for predicting body fatness in both boys and girls between 10 and 15 y of age (23). In the present study, at age 37 y, S4SF was a better predictor of body fatness than was BMI. When we looked at separate skinfolds, body fatness was strongest correlated with the

TABLE 2
Absolute risk (AbR) and relative risk (RR) of having a high percentage body fat (≥25% for men) at the age of 37 y for tertiles of adolescent BMI and adolescent sum of 4 skinfolds thicknesses (S4SF), stratified by age[1]

	Age 12 y (n_{BMI} = 101, n_{S4SF} = 100)			Age 13 y (n = 131)			Age 14 y (n = 132)			Age 15 y (n = 130)			Age 16 y (n = 60)		
Boys	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR
Low BMI	0.21	Ref		0.20	Ref		0.23	Ref		0.26	Ref		0.30	Ref	
Medium BMI	0.24	1.18	(0.48, 2.88)	0.21	1.02	(0.45, 2.33)	0.27	1.20	(0.58, 2.48)	0.23	0.89	(0.42, 1.87)	0.20	0.67	(0.22, 2.01)
High BMI	0.44	2.14	(1.00, 4.59)	0.41	2.00	(1.01, 3.96)	0.41	1.80	(0.94, 3.45)	0.33	1.27	(0.65, 2.48)	0.25	0.83	(0.30, 2.29)
P for trend[2]		0.04			0.03			0.07			0.47			0.72	
Low S4SF	0.12	Ref		0.16	Ref		0.22	Ref		0.14	Ref		0.15	Ref	
Medium S4SF	0.29	2.43	(0.84, 6.98)	0.16	0.98	(0.37, 2.55)	0.19	0.88	(0.38, 2.01)	0.14	0.98	(0.34, 2.79)	0.15	1.00	(0.23, 4.37)
High S4SF	0.48	4.00	(1.50, 10.70)	0.50	3.07	(1.47, 6.43)	0.50	2.30	(1.23, 4.29)	0.53	3.83	(1.73, 8.47)	0.45	3.00	(0.95, 9.48)
P for trend[2]		< 0.01			< 0.01			< 0.01			< 0.01			0.03	

[1] Low, medium, and high designations for BMI and S4SF indicate age-specific tertiles of distribution. CL, confidence limit. The interaction of BMI tertiles and age was significant ($P < 0.10$). The interaction of S4SF tertiles was not significant ($P = 0.90$).

[2] Logistic regression analysis.

TABLE 3
Absolute risk (AbR) and relative risk (RR) of having a high percentage body fat (≥35% for women) at the age of 37 y for tertiles of adolescent BMI and adolescent sum of 4 skinfold thicknesses (S4SF), stratified by age[1]

	Age 12 y (n = 104)			Age 13 y (n = 152)			Age 14 y (n = 151)			Age 15 y (n = 147)			Age 16 y (n = 74)		
Girls	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR	AbR	RR	95% CL of RR
Low BMI	0.26	Ref		0.31	Ref		0.22	Ref		0.24	Ref		0.24	Ref	
Medium BMI	0.29	1.14	(0.53, 2.46)	0.22	0.70	(0.36, 1.36)	0.27	1.25	(0.63, 2.48)	0.31	1.25	(0.65, 2.39)	0.21	0.87	(0.30, 2.47)
High BMI	0.46	1.78	(0.91, 3.47)	0.41	1.31	(0.78, 2.21)	0.40	1.82	(0.98, 3.39)	0.45	1.83	(1.03, 3.28)	0.40	1.67	(0.71, 3.89)
P for trend[2]		0.08			0.29			0.05			0.03			0.21	
Low S4SF	0.17	Ref		0.24	Ref		0.18	Ref		0.22	Ref		0.12	Ref	
Medium S4SF	0.30	1.82	(0.74, 4.45)	0.22	0.92	(0.45, 1.88)	0.16	0.87	(0.37, 2.08)	0.22	0.98	(0.47, 2.05)	0.21	1.74	(0.47, 6.48)
High S4SF	0.54	3.26	(1.48, 7.19)	0.50	2.13	(1.21, 3.75)	0.56	3.11	(1.64, 5.90)	0.56	2.51	(1.41, 4.46)	0.52	4.33	(1.40, 13.37)
P for trend[2]		< 0.01			< 0.01			< 0.01			< 0.01			< 0.01	

[1] Low, medium, and high designations for BMI and S4SF indicate age-specific tertiles of distributions. CL, confidence limit. The interaction of BMI tertiles and age ($P = 0.90$) and of S4SF tertiles and age ($P = 0.61$) were not significant.

[2] Logistic regression analysis.

subscapula skinfold in men and the triceps skinfold in women (data not shown). But more interestingly, adolescent skinfold thickness showed, longitudinally, also to be a better predictor for high adult body fatness, in comparison to adolescent BMI: adolescents in the highest tertile of the S4SF distribution had about 2 times the relative risk of becoming an adult with high body fatness, in comparison with adolescents in the highest tertile of the BMI distribution. Moreover, in boys aged 16 y, a higher BMI was not associated with a higher risk to become an adult with high body fatness.

In our study population, both S4SF and adolescent skinfold thickness were better predictors of adult body fatness than was adolescent BMI. Adolescent subscapular skinfold thickness was the best predictor of adult body fatness in boys, and adolescent biceps skinfold thickness was the best predictor of adult body fatness in girls. Both of these single skinfold thickness measures were better predictors of adult body fatness than was S4SF. This could indicate that only one skinfold thickness needs to be measured in adolescents to obtain a good prediction measure for adult body fatness. However, this has not been investigated before. Generally, if only one skinfold is measured, it is the triceps skinfold; in other cases, triceps skinfold thickness is measured in combination with subscapular skinfold thickness to determine body fatness at the time of measurement. As far as we know, single skinfold thicknesses have not been tested to predict body fatness later in life. Therefore, more and larger studies are needed to confirm our results before any recommendations can be made about the measurement of only one single skinfold in adolescents to predict adult body fatness.

Hughes et al (18) had already recommended in 1997 that skinfold thickness measurements should be used to monitor obesity in children, because of its higher sensitivity. The advantage of using BMI as a screening tool to assess overweight in adolescence is that weight and height are readily available and easy to measure (53). However, the measurement of skinfold thickness is also feasible for use in the field, is relatively inexpensive, and is generally acceptable to the child; furthermore, the equipment needed for such measurement is portable (19).

A possible drawback of the present study was the relatively low representativeness of the study population for the general Dutch population. Most of the subjects (96%) reported to have Western European parents. The remaining 4% of the subjects had 1 or 2 parents of Asian (Indonesia, Java, and China) or Caribbean (Suriname, Curaçao, and Netherlands Antilles) ethnicity. The educational level of the participants was rather high compared with that of the general Dutch population: 53.6% completed a higher vocational or university education. In comparison, 26.4% of the general Dutch population of the same birth years had completed a higher vocational or university education (54). This difference can be ascribed to the selection of 2 schools in Amsterdam and Purmerend, which were both schools for higher secondary education. Furthermore, the subjects who participated during adolescence, but not at an adult age, had, on average, a higher BMI and S4SF at a mean age 13 y than did subjects who did participate at a mean age 37 y. For women, these differences at adolescence were statistically significant. However, none of our data indicate that these drawbacks influenced our results or conclusion. Because we looked at tertiles of BMI and the sum of skinfold thicknesses, only the thresholds for the tertiles would have shifted upward when more overweight adolescents were included. This would have no or only a small effect on the relative risks, because overweight during adolescence predicts overweight at adulthood. Therefore, the associations found between adolescent BMI and S4SF and adult body fatness in our study population would probably not have been different in the original cohort or in the general population.

Prevention of excessive (fat) weight gain in critical periods of obesity development could prevent, or temper, adult overweight and its complications. In the present study, we showed that both male and female adults with high body fatness had higher skinfold thicknesses during adolescence. Therefore, the measurement of adolescent skinfold thickness would yield a simple risk indicator for high adult body fatness, better than the measurement of adolescent BMI. In addition, adolescents with large skinfold thicknesses could be a good target group for secondary weight-gain prevention programs. Finally, as early as the age of 13 y, a difference in mean skinfold thickness was present between adolescents who did and did not become adults with high body fatness, which indicates that weight-gain prevention should start before adolescence.

In conclusion, high adult body fatness is better predicted by adolescent skinfold thickness than by adolescent BMI. Skinfold thickness should therefore be used as the preferred screening tool to determine which adolescents are at increased risk of becoming adults with high body fatness. Weight-gain prevention programs should therefore focus on adolescents with large skinfold thicknesses. Appropriate cutoff values for skinfold thickness still need to be assessed in larger populations.

This study is part of the multidisciplinary NHF-NRG (Netherlands Heart Foundation–Netherlands Researchprogramme Weight Gain Prevention), of which the program committee consists of HCG Kemper, FJ Kok, D Kromhout (chair), and WHM Saris. The principal investigators are J Brug, W van Mechelen, EG Schouten, JC Seidell, MA van Baak, MJM Chin A Paw, and AJ Schuit; the project-coordinators are SPJ Kremers and TLS Visscher.

The authors' responsibilities were as follows—ACJN, LLJK, TLSV, JWRT, HCGK, AJS, WvM, and JCS: conceived the idea for the analyses; ACJN: analyzed the data; HCGK: initiated and directed the AGAHLS; WvM: undertook supervision of the study after HCGK; all authors: contributed to the writing of the manuscript. None of the authors had a conflict of interest.

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