Published in final edited form as:

Gen Hosp Psychiatry. 2008 ; 30(5): 458–466. doi:10.1016/j.genhosppsych.2008.06.008.

Measurement matters in the association between early adolescent depressive symptoms and body mass index

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Abstract

Objective—To examine associations between depressive symptoms and body mass over one year during early adolescence and to assess how the associations might differ depending upon whether self-reported or directly measured height and weight were used.

Method—Participants were 446 sixth-grade Seattle students. Depressive symptoms were assessed using the Mood and Feelings Questionnaire. Regression models were used to examine whether baseline depression status was associated with 12-month BMI (using self-reported height and weight), and whether baseline overweight status was associated with 12-month depressive symptom score. Analyses were re-run among a sub-sample ($n = 165$) who had height and weight directly measured.

Results—Using BMI derived from self-reported values, depressed males had a significantly *lower* BMI than non-depressed males, while depressed females had a significantly *higher* BMI than non-depressed females, after adjusting for covariates. Among a sub-sample using measured height and weight values, however, depression was no longer associated with BMI in either gender. Baseline overweight status did not predict 12-month depression score.

Conclusions—Observed associations between depression and subsequent BMI were explained by differential misclassification of self-reported height and weight by depression status and gender. Direct measurement of height and weight may be necessary to ensure validity in studies of adolescent depression and weight-related outcomes.

Keywords

Depression; body mass; overweight/obesity; adolescence; differential misclassification

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INTRODUCTION

Among US adolescents both obesity and depression have become increasingly significant public health problems [1,2]. Evidence suggests an association between the two health conditions. Cross-sectional studies among population-based samples have consistently reported an association between depression and obesity among early adolescent youth [3–5]. Associations between the two conditions have also been observed in longitudinal studies. Depressed adolescents were observed to have a higher body mass index (BMI) [6,7] and an increased risk for overweight/obesity [7–9] in adulthood. Only one study, to our knowledge, has examined shorter term temporal associations within adolescence. Within a cohort of students grades 7 to 12, depressed mood was associated with elevated risk for obesity among those who were initially normal weight and with elevated risk for persistence of obesity among those who were initially obese after one year [10]. It is also possible that the reverse pathway from overweight/obesity to depression could occur through psychosocial processes involving stigma, social isolation, and low-self esteem. However, few studies have examined this pathway, and the results to date are inconsistent [10,11].

While considerable evidence regarding an association between adolescent depression and obesity in adulthood and limited evidence for an association between obesity during adolescence and depression during adulthood has been reported, no studies to our knowledge have explored these possible pathways within a specific developmental window in early adolescence. Understanding short-term temporal associations between these important public health problems early in the life span can help to identify opportunities for developmentally appropriate preventive interventions.

Of the cited longitudinal studies examining associations between depression and body mass, only one used an objective measure of height and weight to calculate body mass [9]. The method of height and weight measurement is an important consideration. Compared to measured values, weight tends to be under-reported and height over-reported among adolescents [12–15]. Despite observed inaccuracies, it has been argued that the discrepancy between reported and measured height and weight is small, and would have minimal impact on findings in epidemiologic studies [16–18]. However, no studies to our knowledge have considered the possible differential misreporting of height and weight by depression status in any age group. Depressed individuals are more prone to negative self-perceptions [19] and thus may perceive their height and weight differently. If BMI derived from self-reported height and weight were differentially biased between depressed and non-depressed individuals, then associations between depression and BMI may be spuriously overestimated.

In this study, we examined the prospective association between depression status and body mass index (BMI) based on self-reported height and weight and the association between initial overweight status and subsequent depression score over the course of one year among a sample of sixth-grade public middle school students. We hypothesized that elevated depressive symptoms would be associated with higher subsequent BMI and that overweight would be associated with later increased levels of depressive symptoms. We also assessed the impact of bias due to self-reported height and weight on the estimated associations, and we hypothesized that measurement error would have little impact.

METHODS

Setting and participants

This study was approved by the University of Washington Human Subjects' Division. We used data from the Developmental Pathways Project, a two-year prospective cohort study of sixth grade adolescents who were recruited during the fall of 2002 and 2003 from four Seattle, WA

public middle schools. Briefly, the main purposes of the study were to study antecedents, phenomenology and outcomes for co-occurring and non-co-occurring depression and conduct problems during early adolescence [20].

Schools were selected to represent the racial, ethnic, and socio-economic diversity of students enrolled in the Seattle Public School District. After excluding youth who were non-English speaking or developmentally disabled ($n = 43$), 2,253 students were eligible for participation. A total of 1,737 students (77.0%) completed an in-school screening questionnaire that included items about depressive symptoms and conduct problems from the Mood and Feelings Questionnaire (MFQ) and the Youth Self Report (YSR) [21]. Six-hundred ninety-six students were randomly selected from four groups according to their screening scores (high depression and low conduct problem, high depression and high conduct problem, low depression and high conduct problem, low depression and low conduct problem) with the intention of representing the four groups in a ratio of 1:1:1:2, respectively, thus oversampling students scoring high on either or both of the depression or disruptive behavior dimensions. A high score was defined as being >0.5 standard deviations above the sample mean for the MFQ for depression or the YSR externalizing scale for conduct problems. Informed consent was provided by 446 (64.0%) of the students selected and their primary caregivers. Replacement sampling from the four groups was conducted to achieve the target sample size and composition.

Measures

The main constructs of interest in this study were depressive symptoms and body mass. These measures were administered at the longitudinal study baseline interview (2–3 months following the initial screening) and at 12 months after baseline. Trained research interviewers conducted assessments in the family home or at another location that was convenient for the family.

The 33-item Mood and Feelings Questionnaire (MFQ) [22] was used to assess symptoms of depression. The MFQ is designed for children ages 8 to 18 years. Scores from the MFQ are highly correlated with DISC depression diagnoses and the Child Depression Inventory [23]. For this analysis, only the child's responses were used because self reports were shown to be more accurate than others' reports of internalizing symptoms [24]. We used the same MFQ cutoff score to define depression status as had been used to select adolescents for study participation based on screening scores. A state of elevated depressive symptoms was defined as a MFQ score of 15 or higher at the baseline visit which represents a score 0.5 standard deviations above the sample mean at screening. Although this does not reflect a clinical diagnosis of depression, we were interested in studying those children with "subthreshold" depression because children with elevated depressive symptoms who do not cross diagnostic thresholds have been found to have substantial psychosocial impairment and are at increased risk for subsequent major depressive episodes and substance abuse [25,26]. For brevity, those participants scoring at this cutoff or higher at baseline will be referred to as "depressed".

Self-reported height and weight were obtained at baseline and follow-up and were used to calculate participants' BMI ($weight\ in\ kilograms / height\ in\ meters^2$). Using a CDC program [27], the percentiles of participants' BMI compared to 2000 US growth charts were also calculated. Although more commonly defined as "at-risk-for-overweight", for brevity participants will be referred to as "overweight" if they had a BMI greater than or equal to the 85th percentile. Among a sub-sample of participants, direct measurement of weight and height was obtained at the end of in-home interviews using a standardized procedure. Participants were instructed to remove their shoes, any outer layers of clothing, and any heavy items from their pockets before weight measurements were taken. Weight was then measured once using an electronic scale of uniform brand and model and recorded by the interviewer to the nearest half pound. For height measurements, participants were asked to stand on a hard floor surface with their backs to a bare wall against which a tape measure had been extended; and height

was recorded. All measured values were rounded to the nearest inch or pound for consistency with self-reported measures. “Self-reported BMI” and “measured BMI” will be used to refer to BMI calculated from self-report and measured height/weight, respectively.

Demographic characteristics including annual household income, race/ethnicity, and primary caregiver’s education level were obtained from a questionnaire for primary caregivers. Pubertal development was ascertained through self-report using the Physical Development Scale (PDS) which classifies girls and boys according to the five Tanner stages with “1” indicating pre-pubertal and “5” indicating post-pubertal stage. [28]. The PDS was found to be highly correlated with physician Tanner ratings ($r = 0.82$) [28].

Statistical analysis

Chi-square and t-tests were used to test differences in baseline characteristics by depressive symptom status and by overweight status. Because of some reported differences in the association between depression and body mass by gender [9], we tested differences within each gender as well as within the overall sample. Cross-sectional correlations between BMI and log-transformed MFQ score at baseline and 12-months were calculated using Pearson correlation coefficients. A log transformation was used because of the right-skewed distribution of the MFQ scores. Robust linear regression models were used to examine the temporal association between depressive symptoms and BMI. We examined the pathway from baseline depressive symptom status to BMI after 12-months using depression (MFQ score ≥ 15) as the exposure and self-report BMI (continuous) at 12-months as the outcome. The reverse pathway was examined using baseline overweight status as the exposure and subsequent depressive symptom score (log-transformed) measured at 12-months as the outcome. Because of the intentional over-sampling of participants with high depressive symptom scores, sampling weights were included in the regression models for this pathway.

To adjust for potential confounding, we chose the following covariates to include in statistical models *a priori* because of their likely association with both depression and BMI: gender, annual household income (< \$25,000, \$25,000–\$34,999, \$35,000–\$49,999, \$50,000–\$74,999, \$75,000–\$99,999, $\geq$ \$100,000), education of the primary caregiver (less than high school graduate, high school graduate, some college, bachelor’s degree or post-baccalaureate education), physical development (Stage 1 or 2, 3, 4 or 5), and race/ethnicity (Black or Pacific Islander, Other) as covariates. We chose this categorization for race/ethnicity because we observed a greater proportion of Black and Pacific Islander youth among study participants who were depressed or overweight at baseline. The baseline value of the outcome (BMI or MFQ score) was also included as a covariate. By doing this, the coefficient for the exposure of interest reflects the difference between exposure groups in the change in the outcome variable from baseline to 12-months.

Because prior literature suggested that associations were dependent on gender [9], we also included a depression $\times$ gender interaction term to test for a modifying effect of gender on the association between depression and BMI. If the Wald’s test for the interaction term was statistically significant, then we presented gender-stratified results.

We used measured height and weight information collected from a sub-sample of the study cohort to conduct sensitivity analyses exploring the potential impact of depression status and gender-related bias associated with self-report of height and weight on the pathway between depression to subsequent BMI. A high percentage of the 368 participants with self-reported BMI had measured BMI at 12-months (92.9%), but a much smaller portion had measurements at baseline (51.1%). There were no statistically significant differences between the full sample and the sub-sample in MFQ score or self-reported BMI at either timepoint or within either gender.

T-tests were used to compare differences in measured and self-reported BMI within groups according to baseline depression status and gender. To evaluate the impact of the self-report bias, we re-fit fully adjusted regression models among the sub-sample with measured BMI values at *both* timepoints using baseline measured BMI as a covariate and 12-month measured BMI as the outcome. To assess whether any differences in the composition of the sub-sample could account for observed changes in the results, we then re-ran regression models using *self-reported* BMI at baseline and 12-months among this restricted sub-sample.

We conducted other sensitivity analyses. Because of the oversampling of students with high externalizing symptom scores, we fit additional regression models including baseline externalizing symptom score status (elevated: YSR ≥ 12 ; normal: YSR < 12) as a covariate. We also examined the use of different cutpoints for depression and overweight. Regression models were re-fit using depression defined as an MFQ ≥ 20 and overweight as a measured BMI percentile ≥ 95 among the sub-sample of participants with measured BMI at both timepoints. All statistical analyses were conducted using Stata 8.0 (Stata Corporation, College Station, TX).

RESULTS

Of the 446 participants, 53.8% were male, and 46.2% were female. The mean age at baseline was 12.0 ± 0.4 years. MFQ scores were available for all 446 participants at baseline and 380 (85.2%) at 12-months. The mean MFQ scores at baseline were 10.6 ± 8.2 for males and 10.1 ± 9.1 for females. Self-reported height and weight data were available for 423 (94.8%) and 368 (82.5%) participants at baseline and 12-month visits, respectively. The mean baseline BMI was 20.2 ± 4.6 kg/m² among males and 20.0 ± 5.6 kg/m² among females. From baseline to 12-months, there was a significant increase in BMI from baseline to 12-months of 1.1 kg/m² among males ($p < 0.001$) and 1.3 kg/m² among females ($p = 0.001$).

Demographic and other baseline characteristics were compared across baseline depression status, stratified by gender (Table 1). At the designated MFQ cutoff, 26.7% of boys and 22.8% of girls were classified as depressed. Among both males and females, depressed participants were more likely to be Black or Asian-Pacific Islander, to live in a lower income household, to have a primary caregiver with lower educational attainment, and to have a higher baseline BMI. Among females, a higher proportion in the depressed group compared to the non-depressed group was in the later stages of pubertal development. In general, female participants were in later developmental stages than males. Participant characteristics were also compared by baseline overweight status (data not shown). At baseline, 30.3% of males and 22.4% of females were overweight. Among both genders, overweight participants had significantly higher baseline depressive symptom scores. Among females only, overweight participants were more likely than those not overweight to have a low household income, be of Black or Pacific Islander race/ethnicity, and be in later stages of physical development.

Crude cross-sectional correlations between logarithmic MFQ score and BMI were assessed at each visit. Among males, a statistically significant positive correlation between self-report BMI and log-transformed MFQ score was observed at baseline ($r = 0.15$, $p = 0.026$), but was no longer present at 12-months ($r = 0.003$, $p = 0.97$). Among females, BMI and log-transformed MFQ score were significantly correlated at both timepoints (Baseline: $r = 0.24$, $p = 0.009$; 12-months: $r = 0.25$, $p = 0.001$).

Depression to BMI Pathway

Mean BMI was ascertained at each assessment for groups of males and females defined by their baseline depression status (Figure 1). There was no significant difference in 12-month BMI between adolescents with and without depression after adjusting for race, income,

education, gender, and pubertal status ($\beta = 0.49$, $p = 0.27$) and after additionally adjusting for baseline BMI ($\beta = -0.17$, $p = 0.61$). However, a statistically significant interaction between baseline depression and gender was observed ($p < 0.001$), suggesting that the association between depressive symptoms and later BMI varied by gender. Results of gender-specific regression models are shown in Table 2 and described below.

Among males, BMI after one year was not significantly different between the depressed and non-depressed participants after adjusting for initial covariates ($\beta = -0.32$, $p = 0.59$). After additional adjustment for baseline BMI, however, depressed males had a 1.18 kg/m^2 lower BMI at 12-months than non-depressed males ($p = 0.004$). Inclusion of baseline BMI in this model, which was found to be positively associated with depression, suggests that depressed males experienced less increase in BMI over one year than non-depressed males. Among females, a different pattern emerged. Depressed females had a significantly higher BMI at 12-months than non-depressed females after adjusting for initial covariates ($\beta = 2.75$, $p < 0.001$) and after additional adjustment for baseline BMI ($\beta = 2.49$, $p < 0.001$). The magnitude and statistical significance of the associations within both genders were essentially unchanged after further adjustment for baseline externalizing symptom score.

However, results of sensitivity analyses among a sub-sample of participants with measured height and weight at baseline and 12-months suggested that these gender-dependent associations were largely affected by bias due to self-reporting of height and weight, contrary to our hypothesis. Table 3 shows mean values for measured and self-report BMI and the mean difference between the two. The discrepancy between BMI based measured and self-report values differed according to depression status, gender, and study visit. Among boys, depressed compared to non-depressed participants had a more accurate self-reported BMI at baseline, but a less accurate self-report BMI at 12-months. Girls showed the reverse pattern over time. After excluding one extreme outlier at baseline, depressed girls under-reported more at baseline than non-depressed girls, but after 12-months depressed girls had a more accurate self-report BMI. Examination of cross-sectional correlations showed that among females measured BMI and log-transformed MFQ scores were significantly correlated at both study visits (Baseline: $r = 0.22$, $p = 0.037$; 12-month: $r = 0.22$, $p = 0.006$), but no correlations were found among males at either visit (Baseline: $r = 0.09$, $p = 0.36$; 12-months: $r = 0.07$, $p = 0.35$). As shown in Table 4, after restricting the sample to subjects who had measured BMI at both baseline and 12-months (Boys: $n = 86$; Girls: $n = 79$), regression models no longer showed significant prospective associations within either gender between baseline depression and BMI when calculated using measured height and weight (males: $\beta = 0.12$, $p = 0.70$; females: $\beta = 0.54$, $p = 0.27$). When using a higher cutoff for depression status ($\text{MFQ} \geq 20$), the results were nearly identical. The results using self-reported BMI with the restricted sample were very similar to the original findings from the full sample suggesting that the difference in results using measured BMI are not attributable to different characteristics in the composition of this sub-sample.

Pathway from overweight to depression

The pathway from initial overweight status to subsequent depression status was also examined. Based on regression models, the mean MFQ score at 12-months was not significantly different between participants who were overweight and normal weight at baseline after adjusting for initial covariates ($\beta = 0.12$, $p = 0.39$) and also for baseline MFQ score ($\beta = -0.08$, $p = 0.52$). There was no significant gender difference in the association between initial overweight status and later depressive symptom scores ($p = 0.55$), and thus no gender-specific models are shown. Results were similar when overweight status was classified using measured rather than self-reported BMI and when using a higher cutoff for overweight status (BMI percentile ≥ 95).

Further, inclusion of baseline externalizing symptom status did not alter the findings significantly.

DISCUSSION

Initial findings in our young adolescent sample showed that having elevated depressive symptoms in 6th grade was predictive of decreasing self-reported BMI among males and increasing BMI among females. However, this result was largely explained by differential measurement error of height and weight by depressed and non-depressed adolescents. Re-analyses using measured BMI values that were available for a subset of the sample revealed no significant associations between depression and later BMI within either gender, although among females strong positive cross-sectional correlations between measured BMI and depressive symptom scores were observed at initial and 12-month assessments.

Our initial results for females using self-reported BMI were consistent with other studies examining associations between adolescent depression and subsequent obesity and BMI based on self-reported height and weight. A prospective cohort study of college students found a greater risk for obesity in later adulthood among individuals who were initially depressed [8, 9]. In their prospective study of children in grades 7 to 12, Goodman et al. found that over the course of one year, depression was associated with increased risk for obesity among children who were initially normal weight and increased risk of persistence of obesity among those who were initially obese [10].

The use of self-reported height and weight in these studies, however, may have been a major shortcoming. In our study, sensitivity analyses showed that self-reported height and weight were differentially biased and likely explained the original gender-dependent associations between depressed mood and BMI. Studies have found that adolescents are likely to under-report their weight and over-report their height with girls tending to under-report weight to a greater degree [12–15]. No studies to our knowledge have explored biases in self-reported height and weight by depression status. In this study, we found that the accuracy of reporting differed by both gender and depression status. This differential misclassification of outcome by exposure status affected our findings dramatically, as shown by non-significant differences in measured 12-month BMI by initial depression status within both genders.

Individuals who suffer from depression are more prone towards negative self-perceptions and greater self-criticality [19]. It has been suggested that this lower self-appraisal may actually be more realistic than the optimistic self-appraisal of non-depressed persons [29]. Prior studies have shown that females with depression have poorer body image and more negative self-attributions than males with depression [30,31]. Furthermore, ideal body type appears to differ by gender where females in the U.S. are more likely than males to perceive thinness as desirable [32]. Thus, negative body image among depressed females may result in them perceiving their weight less optimistically and result in a higher, or relatively less under-reported BMI compared to non-depressed females. In contrast, males do not exhibit this preference for thinness to the same degree and may even perceive thinness as less desirable during adolescence. Less favorable self-perception among depressed males may cause them to under-report their BMI to a greater degree than non-depressed males. In light of these opposing patterns, gender differences in associations between depression and BMI may be exaggerated when using self-report height and weight. This potential differential bias by depression status and gender should be explored in future studies.

Despite these issues with self-reported height and weight, there is evidence from prior research that supports a temporal association between depression and body mass, particularly among girls. Defining obesity based on objectively measured height and weight, Richardson et al

found that in a cohort of adolescents in New Zealand females with depression were at greater risk for obesity in adulthood [9]. Several methodological features of the current study may at least partially explain why findings differed from those of the previous study. First, the sub-sample with measured height and weight in the current study was small, thus reducing power to detect differences. Another important difference was the age of participants and duration of follow-up. In the current study, we were interested in proximal associations between depression and body mass over a brief developmental period and within a narrow age range during early adolescence. However, in Richardson's study, the duration of follow-up ranged from five to 15 years and depression was assessed in children from ages 11 to 21 years. It is possible that the latent period between the onset of depression and the effect on body mass is longer than one year and/or the effect of depression is more pertinent in during later adolescence. Finally, the phenomena of adolescent depression and obesity may have been associated differently in New Zealand in the 1980's and '90's than in the U.S. in the current decade.

While there are a number of plausible explanations for an association between overweight/obesity preceding an increase in depression symptoms, this pathway was not confirmed in our study using overweight classification based on either self-report or measured BMI. Few studies have examined this particular pathway in adolescence, and results have been inconsistent [10,11]. One possible reason for the lack of an association in this study is the relatively short duration. Perhaps the theorized psychosocial states that result from overweight/obesity (such as low self-esteem, stigma, and social isolation) and lead to increased depressive symptoms are slower to develop, particularly for children at this early stage of adolescence. Another possibility is that body image is more relevant to depression than actual body mass. It is possible that an association would be found using a measure of self-perception of body image in place of overweight status. Cross-sectional studies have shown that youth seeking weight loss treatment are more likely to be depressed than those in the general community population [33].

The current study had several limitations. Despite using a standardized procedure to measure height and weight, the measurements could still be subject to some inaccuracy. Also, it should again be emphasized that for our sensitivity analyses we had a restricted sample. However, analyses using self-report BMI for the full and restricted samples yielded similar findings which lend credence to the findings regarding depression and measured BMI in the smaller sample. Another limitation is generalizability to other age groups. The specific developmental period of early adolescence that was examined in the current study may be one where self-report is particularly inaccurate. Older adolescents may have attained a more stable height and weight. Thus, the impact of measurement error may be expected to decrease over the course of adolescence. Finally, as with most longitudinal studies, we had problems with missing data over time. Of the 423 participants completing the MFQ and self-reporting height and weight at baseline, 55 were missing self-reported BMI and 61 were missing a MFQ score at 12-months. Subjects with missing data at the 12-month assessment had higher depression scores and higher self-report BMI at baseline than those without missing data. However, when analyses were repeated using multiple imputation to account for bias that might have been introduced by attrition, results were not altered.

Some researchers have argued that discrepancies between measured and self-reported height and weight are minor and have little impact on results of epidemiologic studies [16–18]. However, our findings suggest that in studying the association between adolescent depression and BMI, the impact of the differential misclassification may be substantial. Additional research is needed to identify developmental periods where self-reported height and weight are more or less valid and where depression is more or less strongly related to physical stature. Also, further examination of misclassification of height and weight according to mental health status would help inform future research on depression and weight-related conditions.

Acknowledgements

This study was funded by grant MH63711 from the National Institutes of Mental Health and Drug Abuse (NIMH), and a grant from the Nesholm Foundation in Seattle, WA. In addition, Mr. Rhew was supported by grant number T32 HD052462 from the National Institute of Child Health and Human Development, NIH, and Dr. Richardson was funded by a K23 award from the NIMH (3K23 MH069814-01A1). The authors wish to thank Melissa Tracy, MPH, and Elena Kuo, MPH, for their assistance with data management. We are also grateful to the Seattle children and parents who participated in the Developmental Pathways Project.

References

1. Ogden CL, Flegal KM, Carroll MD, et al. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *Jama* 2002;288:1728–32. [PubMed: 12365956]
2. Lagges A, Dunn D. Depression in children and adolescents. *Neurol Clin N Am* 2003;21:953–60.
3. Swallen KC, Reither EN, Haas SA, et al. Overweight, obesity, and health-related quality of life among adolescents: the National Longitudinal Study of Adolescent Health. *Pediatrics* 2005;115:340–7. [PubMed: 15687442]
4. Needham BL, Crosnoe R. Overweight status and depressive symptoms during adolescence. *J Adolesc Health* 2005;36:48–55. [PubMed: 15661596]
5. Richardson LP, Garrison MM, Drangsholt M, et al. Associations between depressive symptoms and obesity during puberty. *Gen Hosp Psychiatry* 2006;28:313–20. [PubMed: 16814630]
6. Pine DS, Goldstein RB, Wolk S, et al. The association between childhood depression and adulthood body mass index. *Pediatrics* 2001;107:1049–56. [PubMed: 11331685]
7. Franko DL, Striegel-Moore RH, Thompson D, et al. Does adolescent depression predict obesity in black and white young adult women? *Psychol Med* 2005;35:1505–13. [PubMed: 16164774]
8. Barefoot JC, Heitmann BL, Helms MJ, et al. Symptoms of depression and changes in body weight from adolescence to mid-life. *Int J Obes Relat Metab Disord* 1998;22:688–94. [PubMed: 9705031]
9. Richardson LP, Davis R, Poulton R, et al. A longitudinal evaluation of adolescent depression and adult obesity. *Arch Pediatr Adolesc Med* 2003;157:739–45. [PubMed: 12912778]
10. Goodman E, Whitaker RC. A prospective study of the role of depression in the development and persistence of adolescent obesity. *Pediatrics* 2002;110:497–504. [PubMed: 12205250]
11. Mustillo S, Worthman C, Erkanli A, et al. Obesity and psychiatric disorder: developmental trajectories. *Pediatrics* 2003;111:851–9. [PubMed: 12671123]
12. Elgar FJ, Roberts C, Tudor-Smith C, et al. Validity of self-reported height and weight and predictors of bias in adolescents. *J Adolesc Health* 2005;37:371–5. [PubMed: 16227121]
13. Danubio ME, Miranda G, Vinciguerra MG, et al. Comparison of self-reported and measured height and weight: Implications for obesity research among young adults. *Econ Hum Biol* 2008;6:181–90. [PubMed: 17482531]
14. Morrissey SL, Whetstone LM, Cummings DM, et al. Comparison of self-reported and measured height and weight in eighth-grade students. *The Journal of school health* 2006;76:512–5. [PubMed: 17096824]
15. Strauss RS. Comparison of measured and self-reported weight and height in a cross-sectional sample of young adolescents. *Int J Obes Relat Metab Disord* 1999;23:904–8. [PubMed: 10490794]
16. Brooks-Gunn J, Warren MP, Rosso J, et al. Validity of self-report measures of girls' pubertal status. *Child Dev* 1987;58:829–41. [PubMed: 3608653]
17. Shannon B, Smiciklas-Wright H, Wang MQ. Inaccuracies in self-reported weights and heights of a sample of sixth-grade children. *J Am Diet Assoc* 1991;91:675–8. [PubMed: 2040781]
18. Goodman E, Hinden BR, Khandelwal S. Accuracy of teen and parental reports of obesity and body mass index. *Pediatrics* 2000;106:52–8. [PubMed: 10878149]
19. Lewinsohn PM, Gotlib IH, Seeley JR. Depression-related psychosocial variables: are they specific to depression in adolescents? *Journal of abnormal psychology* 1997;106:365–75. [PubMed: 9241938]
20. Vander Stoep A, McCauley E, Thompson K, et al. Universal screening for emotional distress during the middle school transition. *J Emot Behav Disord* 2005;13:213–23.

21. Achenbach, T. Youth Self Report. Burlington, VT: University of Vermont; 2001.
22. Angold, A.; Costello, E. Mood and Feelings Questionnaire (MFQ). Durham, NC: Developmental Epidemiology Program, Duke University; 1987.
23. Kovacs, M. Children's Depression Inventory Manual. North Tonawanda, NY: Multi-Health Systems, Inc; 1992.
24. Costello, EJ.; Angold, A. Chapter 2: Developmental epidemiology. In: Cicchetti, D.; Cohen, DJ., editors. Developmental Psychopathology. New York, NY: John Wiley & Sons; 1995.
25. Lewinsohn PM, Solomon A, Seeley JR, et al. Clinical implications of "subthreshold" depressive symptoms. *Journal of abnormal psychology* 2000;109:345–51. [PubMed: 10895574]
26. Stewart SM, Lewinsohn PM, Lee PWH, et al. Symptom patterns in depression and "subthreshold" depression among adolescents in Hong Kong and the United States. *J Cross Cult Psychol* 2002;33:559–79.
27. CDC. A SAS Program for the CDC Growth Charts. 2005.
28. Petersen AC, Crockett L, Richards M, et al. A self-report measure of pubertal status: Reliability, validity, and initial norms. *J Youth Adolesc* 1988;17:117–33.
29. Alloy, LB.; Abramson, LY. Depressive realism: Four theoretical perspectives. In: Alloy, LB., editor. *Cognitive processes in depression*. New York: Guilford; 1988. p. 223–65.
30. Allgood-Merten B, Lewinsohn PM, Hops H. Sex differences and adolescent depression. *J Abnorm Psychol* 1990;99:55–63. [PubMed: 2307767]
31. Bennett DS, Ambrosini PJ, Kudes D, et al. Gender differences in adolescent depression: do symptoms differ for boys and girls? *J Affect Disord* 2005;89:35–44. [PubMed: 16219362]
32. Wardle J, Williamson S, Johnson F, et al. Depression in adolescent obesity: cultural moderators of the association between obesity and depressive symptoms. *Int J Obes (Lond)* 2006;30:634–43. [PubMed: 16570093]
33. Zeller MH, Saelens BE, Roehrig H, et al. Psychological adjustment of obese youth presenting for weight management treatment. *Obes Res* 2004;12:1576–86. [PubMed: 15536221]

Figure 1.
Mean BMI derived from self-reported height and weight according to baseline depression status and gender

Table 1
Participant baseline characteristics by baseline depression status stratified by gender

Characteristic	Overall sample		Males		Females	
	Depressed (N = 111) n (%)	Not depressed (N = 335) n (%)	Depressed (N = 64) n (%)	Not depressed (N = 176) n (%)	Depressed (N = 47) n (%)	Not depressed (N = 159) n (%)
Race/ethnicity ^{a,b, c}						
White, non-Hispanic	36 (32.4)	165 (49.2)	24 (37.5)	91 (51.7)	12 (25.5)	74 (46.5)
Asian	14 (12.5)	42 (12.6)	4 (6.25)	20 (11.36)	10 (21.3)	22 (13.8)
Black	42 (37.8)	85 (25.4)	23 (35.9)	43 (24.4)	19 (40.4)	42 (26.4)
Native American	6 (5.4)	16 (4.8)	5 (7.8)	8 (4.6)	1 (2.1)	8 (5.0)
Pacific Islander	11 (9.9)	11 (3.3)	7 (10.9)	7 (4.0)	4 (8.5)	4 (2.5)
White, Hispanic	2 (1.8)	16 (4.8)	1 (1.6)	7 (4.0)	1 (2.1)	9 (5.7)
Household income, \$ thousands ^{a,b}						
<25	39 (36.5)	83 (25.2)	22 (35.5)	37 (21.4)	17 (37.8)	46 (29.3)
25–34	11 (10.3)	21 (6.4)	6 (9.7)	10 (5.8)	5 (11.1)	11 (7.0)
35–49	23 (21.5)	46 (13.9)	13 (21.0)	25 (14.5)	10 (22.2)	21 (13.4)
50–74	13 (12.2)	74 (22.4)	6 (9.7)	41 (23.7)	7 (15.6)	33 (21.0)
75–99	12 (11.2)	37 (11.2)	10 (16.1)	27 (15.6)	2 (4.4)	10 (6.4)
100+	9 (8.4)	69 (20.9)	5 (8.1)	33 (19.1)	4 (8.9)	36 (22.9)
Physical development						
Stage 1 or 2	34 (31.8)	97 (29.7)	29 (45.3)	82 (47.4)	5 (11.6)	15 (9.7)
Stage 3	48 (44.9)	168 (51.4)	32 (50.0)	82 (47.4)	16 (37.2)	86 (55.8)
Stage 4 or 5	25 (23.4)	62 (19.0)	3 (4.7)	9 (5.2)	22 (51.2)	53 (34.4)
Overweight ^{a,c}	81 (25.4)	44 (22.3)	25 (40.3)	46 (27.2)	19 (45.2)	35 (23.3)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	12.0 (0.43)	12.1 (0.43)	12.1 (0.43)	12.0 (0.40)	12.1 (0.49)	12.0 (0.46)
Education of caregiver, years ^{a,b,c}	12.4 (4.3)	13.7 (3.6)	12.3 (4.6)	13.7 (3.5)	12.6 (3.9)	13.8 (3.6)
BMI at baseline ^{a,b,c}	21.7 (6.5)	19.6 (4.4)	21.1 (5.1)	19.8 (4.3)	22.4 (8.1)	19.3 (4.5)

^a p<0.05 comparing difference between depressed and not depressed for overall sample based on χ^2 test or t-test

^b p<0.05 comparing difference between depressed and not depressed for males based on χ^2 test or t-test

^c p<0.05 comparing difference between depressed and not depressed for females based on χ^2 test or t-test

Table 2
Regression coefficients for self-reported BMI (kg/m²) at 12-month visit, stratified by gender.

Parameter	Model 1 β (95% CI)	p	Model 2 β (95% CI)	p	Model 3 β (95% CI)	p
Males						
Intercept	20.10 (19.52, 20.68)	<0.001	20.07 (17.76, 22.38)	<0.001	2.67 (0.54, 4.80)	0.014
Depressed	-0.48 (-1.64, 0.67)	0.41	-0.32 (-1.52, 0.87)	0.59	-1.18 (-1.99, -0.37)	0.004
Household income ^a	--	--	0.17 (-0.21, 0.55)	0.37	-0.15 (-0.40, 0.11)	0.25
Education ^b	--	--	-0.68 (-1.33, -0.026)	0.042	-0.33 (-0.77, 0.10)	0.13
Race/ethnicity ^c	--	--	-0.57 (-1.84, 0.71)	0.38	-0.66 (-1.53, 0.21)	0.13
Pubertal stage ^d	--	--	0.78 (-0.092, 1.65)	0.079	0.34 (-0.26, 0.94)	0.26
Baseline BMI ^e	--	--	--	--	0.98 (0.90, 1.06)	<0.001
Females						
Intercept	19.37 (18.80, 19.94)	<0.001	17.20 (14.84, 19.56)	<0.001	7.18 (4.63, 9.73)	<0.001
Depressed	3.16 (1.91, 4.40)	<0.001	2.76 (1.48, 4.03)	<0.001	2.49 (1.44, 3.54)	<0.001
Household income ^a	--	--	0.032 (-0.30, 0.37)	0.85	0.10 (-0.17, 0.38)	0.45
Education ^b	--	--	-0.083 (-0.75, 0.58)	0.81	-0.18 (-0.71, 0.34)	0.50
Race/ethnicity ^c	--	--	2.01 (0.77, 3.25)	0.002	1.20 (0.18, 2.22)	0.021
Pubertal stage ^d	--	--	0.85 (0.038, 1.66)	0.040	0.37 (-0.28, 1.02)	0.27
Baseline BMI ^e	--	--	--	--	0.61 (0.51, 0.71)	<0.001

^aIncome categories: < \$25,000, \$25,000–\$34,999, \$35,000–\$49,999, \$50,000–\$74,999, \$75,000–\$99,999, ≥\$100,000)

^bEducation categories: less than high school graduate, high school graduate, some college, college graduate or further

^cRace/ethnic categories: Black or Pacific Islander, other

^dPubertal stage categories: Stage 1 or 2, Stage 3, Stage 4 or 5

^eBased on self-reported height and weight; modeled as a continuous variable

Table 3
Mean (SD) baseline and 12-month BMI (kg/m²) calculated from self-reported and measured height and weight values, stratified by baseline depressive symptom status and gender

	Boys			Girls			p-value
	Measured	Self-report	Difference	Measured	Self-report	Difference	
Baseline							
Depressed (n = 33 ^a ; 17 ^b)	21.7 (5.6)	21.2 (4.7)	0.4 (4.5)	0.58	23.1 (7.6)	21.3 (5.1)	1.7 (5.1)
Not depressed (n = 67 ^a ; 70 ^b)	20.7 (4.9)	19.9 (4.4)	0.8 (2.2)	0.005	19.9 (4.4)	19.4 (4.0)	0.4 (2.0)
12-month							
Depressed (n = 43 ^a ; 32 ^b)	21.5 (5.5)	20.1 (4.0)	1.4 (4.0)	0.025	24.0 (7.7)	23.9 (7.2)	0.1 (3.1)
Not depressed (n = 138 ^a , 122 ^b)	21.0 (4.7)	21.4 (5.1)	0.4 (1.8)	0.010	20.3 (3.8)	19.8 (4.0)	0.4 (2.5)

^a Boys

^b Girls

Table 4Regression coefficients for *measured* BMI at 12-months stratified by gender

Parameter	Males β (95% CI)	p	Females β (95% CI)	p
Intercept	1.26 (−0.46, 2.98)	0.15	−0.41 (−2.78, 1.96)	0.73
Depressed	0.12 (−0.49, 0.73)	0.70	0.54 (−0.42, 1.51)	0.27
Household income ^a	−0.04 (−0.24, 0.16)	0.73	0.037 (−0.21, 0.28)	0.77
Education ^b	−0.11 (−0.47, 0.26)	0.56	−0.17 (−0.78, 0.43)	0.57
Race/ethnicity ^c	−0.015 (−0.75, 0.71)	0.97	0.48 (−0.54, 1.49)	0.36
Pubertal stage ^d	0.51 (0.05, 0.98)	0.03	−0.012 (−0.58, 0.55)	0.97
Baseline BMI ^e	0.96 (0.90, 1.01)	<0.001	1.09 (1.01, 1.17)	<0.001

^a Income categories: < \$25,000, \$25,000–34,999, \$35,000–49,999, \$50,000–74,999, \$75,000–99,999, ≥\$100,000)

^b Education categories: less than high school graduate, high school graduate, some college, college graduate or further

^c Race/ethnic categories: Black or Pacific Islander, other

^d Pubertal stage categories: Stage 1 or 2, Stage 3, Stage 4 or 5

^e Based on measured height and weight; modeled as a continuous variable