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A Prospective Study of Psychological Distress and Weight Status in Adolescents/Young Adults

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Abstract

Background—The obesity–psychological distress relationship remains controversial.

Purpose—This study aims to assess whether adolescents’ psychological distress was associated with body mass index (BMI) class membership determined by latent class analysis.

Methods—Distress (anxiety, depression) and BMI were measured annually for 4 years in 1,528 adolescents. Growth mixture modeling derived latent BMI trajectory classes for models with 2–11 classes. The relationship of distress to class membership was examined in the best-fitting model using vector generalized linear regression.

Results—BMI trajectories were basically flat. The five-class model [normal weight (48.8%), overweight (36.7%), obese who become overweight (3.7%), obese (9.4%), and severely obese (1.3%)] was the preferred model (Bayesian information criterion=22789.2, $df=31$; $p=0.84$). Greater distress was associated with higher baseline BMI and, therefore, class membership.

Conclusions—Psychological distress is associated with higher BMI class during adolescence. To determine whether distress “leads” to greater weight gain may require studies of younger populations.

Keywords

Obesity; Anxiety; Depression; Adolescence; Growth mixture model; Latent class

Introduction

Obesity is a major public health problem throughout the developed world. Numerous studies have documented an association between obesity and various forms of psychological distress, including anxiety and depressive disorders [1–3]. However, the timing and direction of the relationship between obesity and psychological distress remain

controversial. Some evidence suggests that obesity in childhood and adolescence increases the risk of developing mood or anxiety disorders in adulthood [4, 5]. Other studies demonstrate that depressive symptoms, particularly if they occur early in life, increase the likelihood of obesity in adulthood [3, 4, 6, 7], though prospective longitudinal studies are limited.

Adolescence is a period of significant emotional and physiological maturation as well as a key risk period when anxiety and depressive symptoms increase and mood syndromes develop. Furthermore, although these forms of distress are highly co-morbid in adulthood, anxiety tends to onset earlier in the life course than depression [8]. Anxiety, which is less well studied than depression, has been positively associated with adiposity [9]. Because anxiety, depressive symptoms, and increased adiposity often co-occur, investigators have speculated common causes that underlie the development of psychological distress and obesity [3]. The directionality of influence remains uncertain. With regard to distress influencing weight gain, potential mechanisms have included neurohormonal changes and effects of distress on eating and physical activity behaviors [2, 3, 6, 10]. Assessing whether distress and increased adiposity co-occur or if these psychological and physiological processes can be disentangled during this key developmental period can provide insight into how best to target prevention efforts.

Although adolescence may provide a key window for prevention, there are significant statistical challenges to studying both adiposity and distress. Both the heterogeneity of adolescent populations and the increased within-person heterogeneity that is a hallmark of adolescence create statistical challenges to teasing out subtle differences in body mass index (BMI) and mood trajectories in this developmental period. Recent studies considering BMI or mood trajectories during adolescence suggest that advances in statistical modeling, including growth mixture modeling (GMM) [11, 12], help overcome these challenges. GMM is particularly suited to these types of questions as it generates a latent class structure that captures trajectories over time to which individuals can be empirically assigned. This type of modeling can help to identify subgroups in the population for which the association between distress and BMI is particularly relevant, and also permits testing hypotheses related to class membership.

The purpose of this study was to assess latent BMI trajectory classes (which reflect patterns of change) during adolescence and to examine these in relation to anxiety and depression. Using data from a population-based cohort of adolescents followed over a 3-year period, we sought first to identify BMI patterning over time by modeling different numbers of latent BMI trajectory classes and determining the optimal number of BMI trajectory classes within a model. We then examined whether depressive or anxiety symptoms were associated with class membership in this optimal model after adjusting for relevant sociodemographic characteristics, including gender, socioeconomic status, and race/ethnicity. We hypothesized that anxiety and depressive symptoms would be associated with membership in BMI classes with increased adiposity and with classes which showed increases in BMI over the 3 years of follow-up.

Methods and Procedures

Sample

Data were drawn from Phase 1 of the Princeton School District Study, a longitudinal school-based study of cardiometabolic risk [13, 14]. Students enrolled in grades 5–12 in the Princeton City School District in Greater Cincinnati in 2001–2002 were eligible for participation. Data collection began in September 2001 and ended in May 2005. Written informed consent was obtained from the parent or guardian of participants under 18 years of

age (as well as written student assent) or from the participant if the student was 18 years or older. Students were excluded if they were pregnant, received daily or alternate-day corticosteroid treatment for asthma, or had a disease that would interfere with carbohydrate metabolism. Study visits took place in the school setting or local Children's Hospital per participant preference. These visits included a physical exam performed by trained study staff and completion of a survey which was only completed for students in grades 7 and higher, as survey measures were validated for ages 12 and beyond. All procedures were approved by the participating hospital's Institutional Review Board.

Since the cohort is 95% non-Hispanic black and white, analyses for this study were restricted to these two racial/ethnic groups. Information on race/ethnicity, gender, and socioeconomic status was required for inclusion in these analyses because we felt these may be key factors related to latent class composition. The two other inclusion criteria were: (1) had height and weight measured at baseline and at least one additional wave of data collection and (2) completed the survey at two or more waves of data collection. At study initiation, consent was obtained for 2,257 (61.2%) of the 3,684 eligible students. More girls than boys consented (66.8% versus 56.4%). There were no differences in consent by race/ethnicity or age. Of the 2,257 participants, there were 1,743 (77.2%) with information on race/ethnicity, gender, and socioeconomic status, 1,528 of whom met the two other inclusion criteria. There were no differences by age, race, or gender between those 1,528 students who completed two or more study visits and the 215 who did not. The analysis cohort was 51.2% female and 47.1% non-Hispanic black. Mean age at baseline was 14.4 (standard deviation (SD)=2.1) years. BMI data were available from all four waves of data collection for 78%; 15% had BMI data from three waves and 7% had BMI data from two waves.

Measures

Demographics—Demographic information (race/ethnicity, birth date, and gender) was provided by the school district from administrative records. Age was calculated as exam date minus birth date.

Parent Education—A parent reported his/her own and current spouse/partner's education in nine ordered categories ranging from never attended school to professional training beyond a 4-year college in a short survey completed during the informed consent process. The higher of these was used to define parental education [15]. Analytic categories were: high school or less, some college or vocational training after high school, college, and professional degree beyond college.

Stage of Pubertal Development—Pubertal status (prepubertal, pubertal, and postpubertal) was assessed using a validated protocol based on serum estradiol concentration and the presence or absence of menarche for 2 years in females and serum free testosterone concentration and the stage of axillary hair in males [16]. In females, prepubertal was defined as an estradiol ≤ 11 pg/ml, pubertal was defined as an estradiol >11 pg/ml without menarche or duration of menarche ≤ 2 years, and post pubertal status was defined as the presence of menses for >2 years. In males, prepubertal was defined as a free testosterone ≤ 1.0 pg/ml, pubertal was defined as a free testosterone >1.0 pg/ml and axillary hair $<$ Tanner stage III, and postpubertal status was defined free testosterone >1.0 pg/ml and axillary hair Tanner stage III.

Body Mass Index—Height (RoadRod stadiometer, Quick Medical; North Bend, WA, USA) and weight (SECA 770 digital scale; Hanover, MD, USA) measures were obtained by trained study staff with participants in regular attire with shoes off and pockets empty per protocol [16]. Each parameter was measured twice and the mean was used in analyses.

Psychological Distress—The 20-item Centers for Epidemiological Study-Depression (CESD) scale was used to measure depressive symptoms at each wave [17–19]. To assess anxiety, the trait subscale of the Spielberger State-Trait Anxiety Inventory [20] was included in waves 2–4.

Statistical Methods

We examined study cohort trajectories, rather than age-specific growth trajectories, as this more accurately reflects the structure of the data (groups of students nested within measurement occasions). The 1,528 adolescents were also nested within 1,192 families. Among the families, 75.9% had a single child in the study, 20.2% had two children, 3.3% had three children, and 0.3% had four children in the study. This nesting of subjects within families was accounted for by appropriate sandwich estimator correction of standard errors. We used BMI with explicit adjustment made for age and gender differences in growth as opposed to age–gender standardized BMI *z* scores, as *z* scores are neither available for nor used to define obesity in young adults and BMI has been shown to be a more interpretable measure for longitudinal epidemiological studies [21, 22]. Further, 50.8% of the cohort was postpubertal at baseline; this increased to 72.8% by the end of the follow-up period, suggesting that most of the BMI change would be due to weight rather than changes in height. Since the first measurement of anxiety was not obtained until wave 2, compared to wave 1 for depressive symptoms, analyses with anxiety and depression were conducted separately. Moreover, since participants had to be in seventh grade or higher to complete the survey, which included the psychological distress measures to assess anxiety and depressive symptoms, initial sixth graders (*N*=190) were missing CESD data from wave 1 and initial fifth graders (*N*=142) were missing CESD information from waves 1 and 2 and anxiety data from wave 2 by design. Thus, 1,196 subjects were eligible for measurement of psychological distress at wave 1 and 1,386 were eligible at wave 2. The only other discernable pattern of missingness indicated that loss-to-follow-up occurred more frequently among older children. Consequently, the assumption of missing at random was adopted.

Growth mixture models were used to determine BMI trajectory latent classes [23]. We considered models with 2–11 classes and examined model-fit statistics and resulting trajectory class structures to guide identification of the most appropriate latent class model for our data. These models consider patterns of BMI across the four waves of data collection. BMI trajectories were taken to be quadratic in (centered) time. In theory, one might have a group with high BMI at all time points relative to other groups but whose BMI decreases over time or another group that starts with low BMI but increases over time. A combination of the bootstrap likelihood ratio test [24] and model interpretability was used to guide model selection regarding the optimal number of latent classes [23, 24].

When considering change in BMI over time, it is important to consider autocorrelation (correlated residuals between one observation and the class mean trajectory as well as between prior/subsequent observations within individuals). Preliminary work with our data indicated greater within-person homogeneity (i.e., limited change in individual BMI throughout the study period) than between-person homogeneity (i.e., we noted substantial differences between individuals in the population) in our cohort. We therefore modeled an AR(1) autocorrelation structure that was parameterized to be identical across classes. The adoption of an AR(1) constraint assumes regular study intervals for obtaining measures over time. Although actual timing varied slightly from wave to wave (mean times to follow-up were 0.86, 0.94, and 0.96 years with medians of 0.88, 0.96, and 0.98 years and inter-quartile ranges of 0.21, 0.15, and 0.18 years), tests of alternative approaches yielded similar findings. We therefore report the more easily interpreted AR(1) constraint.

In running models to determine the optimal class number, initially the variance and covariance structure of the intercept, slope, and quadratic terms were estimated freely, but difficulties in model convergence required that slope and quadratic variance and covariance terms be restricted to zero. Consequently, the AR(1) parameterization accommodated residual random structure and these models consistently provided a better fit than models without AR(1).

In each model, the global intercept was modeled on age, gender, and age–gender interaction, and race and the global slope modeled on age. These covariates were constrained to have identical coefficients across the classes. Within each class, BMI variance was assumed to be constant over time, though it was allowed to differ across classes. Models were run with 20 k random starts from which the best 10% were run to full convergence to obtain model estimates and robust standard errors.

After determining the model with the optimal number of latent classes, we examined class composition in that model in relation to depression and anxiety scores, adjusting for sociodemographics, using vector-generalized linear regression (an extension to generalized multinomial modeling). Here, the outcome for each individual comprises a vector of the probabilities of belonging to each of the five classes (probabilistic assignment), and although the sum of these probabilities is 1, each class probability may be a value between 0 and 1. This is as opposed to being assigned simply a categorical value 1 to n that depicts the class in which the individual is most likely to belong (modal assignment). Covariate interpretation in our probabilistic assignment models is the same as for the standard multinomial model. The reference categories for these analyses were average age (14.4 years), normal weight, postpubertal white male, and professionally educated parent. To make depressive and anxiety symptom scales comparable, we explored the association of class membership with respect to 1 SD change in symptom scores (depression SD=9.37, anxiety SD=6.69). Although anxiety and depressive symptoms were measured repeatedly over time, we primarily examined whether levels of anxiety or depression at each wave was associated with BMI latent class trajectory (pattern of BMI change over time). We note that our models do not evaluate change in BMI directly nor do we model the effect of distress on BMI change within each class.

All latent class models were run in *Mplus*, while data manipulation and vector generalized linear regression was undertaken in *R* using the VGAM package. Throughout, 95% confidence intervals are reported.

Results

Description of Key Variables

BMI, anxiety, and depressive symptoms all varied with demographic factors at their initial assessment (Table 1). Females had higher mean levels of distress, black and postpubertal subjects exhibited higher mean levels of BMI, and black adolescents had more depressive symptoms. Adolescents whose parents were less well educated had higher levels of BMI, anxiety, and depressive symptoms. Mean levels of anxiety and depressive symptoms in this sample are similar to those seen in other adolescent populations [19, 20, 25, 26].

Latent Class Models

Determination of Optimal Class Number—We explored latent class models with 2–11 classes. All models yielded similarly patterned latent class trajectories. Although the six-class model was the best-fitting model according to the bootstrap likelihood ratio test, this was followed closely by the five-class model (Table 2), and both yielded just one class

where BMI trajectories were not always increasing; a feature that appeared from five classes onwards and was maintained. The only substantive differences between the five- and six-class models was that the largest two classes in the former (normal weight [class mean BMI=20.5 kg/m²], 48.8% and overweight [25.0 kg/m²], 36.7%), emerged as three classes (light normal weight [19.4 kg/m²], 23.2%; heavy normal weight [21.7 kg/m²], 32.3%; and overweight [25.6 kg/m²], 31.5%), by absorbing 1.5% from the obese-to-overweight class. With changes in Bayesian information criterion=2.4 and *df*=5, it was deemed more parsimonious to adopt the five-class model. Patterning was similar across the five- and six-class models when explored separately by race and by gender (results not shown), so we report results only for the combined five-class model.

The Five-Class Model—Overall, adolescents differed with respect to BMI at the start of the study and these differences remained consistent over time. A notable finding was the limited change in BMI over the 3 years of follow-up for each class. Four of the five classes showed gradual though modest increases in BMI throughout the study and one class exhibited a slight decline in BMI during the last annual follow-up (Fig. 1). The table insert within Fig. 1 provides the trajectory mean intercept (midway through the study), mean rate of change (slope), and mean rate of the rate of change (acceleration) for each class. The five classes identified can be described as: (1) persistently normal weight (48.8%), (2) persistently overweight (36.7%), (3) obese who become overweight (3.7%), (4) persistently obese (9.4%), and (5) severely obese (1.3%).

Looking across the entire study population, the impact of age (per year) on mean BMI was 0.33 kg/m² (95%CI 0.24, 0.42) and on BMI slope was -0.10 kg/m² (95%CI -0.11, -0.09). The differences in BMI per year of age were greater among younger subjects and varied from 0.38 to 0.28 kg/m² across a 10-year age range. Gender differences in mean BMI were negligible [BMI difference=-0.03 (-0.31, 0.26)], though an age-gender interaction for mean BMI indicated that age had a stronger association with BMI among males than females [BMI difference=0.25 (0.12, 0.39)]. Race was associated with mean BMI such that whites had on average lower mean BMI than blacks [BMI difference=-0.64 (-0.92, -0.35)], a difference approximately similar to that of being 2 years younger.

We next examined whether membership in each BMI trajectory class varied in relation to sociodemographic factors using vector generalized linear regression (Table 3). Black males consistently had the highest odds of being in all non-normal weight classes. Individuals living in a household without a college-educated parent had greater odds of membership in a BMI trajectory class with higher mean BMI. These odds rose as the mean BMI of the class increased.

Table 4 summarizes the distribution of depressive and anxiety symptoms across the BMI trajectory classes at each wave. The rank ordering of mean symptom levels across the five BMI classes was consistent over time. For both anxiety and depressive symptoms, the severely obese group exhibited the highest mean symptom level and the normal weight class exhibited the lowest mean symptom level until wave 4. At wave 4, depressive symptom levels in the severely obese class were actually lower than symptom levels in the obese class, and anxiety symptom levels in the severely obese class dropped below all classes except the normal weight class. For both depressive and anxiety symptoms at wave 4, confidence intervals around the point estimates were widest in the severely obese group suggesting either substantial variation in symptom levels within this group or consequences of the small sample size, or both. These findings persisted with adjustment for demographic covariates. Table 5 presents the probability of class membership compared to membership in the normal weight class modeled in relation to a difference of 1 SD in anxiety or depressive symptom scores. The 1 SD difference compares across classes to the normal group within

waves, not across waves within classes. For example, at wave 2, the odds of being in the obese class compared to the normal weight class were slightly higher (1.30) for anxiety than depressive symptoms (1.28).

We initially hypothesized that anxiety and/or depressive symptoms would be associated with initial BMI as well as increases in BMI over the follow-up period. Although four of the five classes exhibited increases in BMI over time, the increase was minimal. Therefore, within any single BMI trajectory class, there was little change in BMI over the course of the study for the class as a whole. Thus, classes were largely differentiated by mean BMI levels at first measurement and because of parallel class trajectories, it was highly unlikely that we would observe an association between depressive or anxiety symptoms and BMI change. Rather, overall mean BMI of each class was most strongly associated with levels of depressive or anxiety symptoms, and this overall mean BMI reflected BMI at baseline.

Discussion

This is one of the first studies to use growth mixture modeling in longitudinal data with repeated measures of BMI to consider the relationship between psychological distress and BMI trajectory class. A value of growth mixture models is that they can help to identify nuanced trajectories within a cohort, thereby providing a more granular picture of the population profile over time. Despite this enhanced capability to detect patterns within a population, we found that BMI trajectory classes were largely static and determined mostly by baseline BMI. This is consistent with some other studies which have suggested that stability in weight status occurs during adolescence despite increased growth acceleration and the changes in adiposity known to be associated with puberty [27, 28].

While most prior studies have focused on depression and weight status, recent work has suggested the importance of considering distress more broadly, particularly when studying children and adolescents given that anxiety symptoms may be more evident at younger ages [29]. In the present study, pattern of findings with regard to anxiety was highly similar to that of depression, and also to the limited set of work that has considered anxiety in relation to weight status during adolescence [29, 30]. With the high comorbidity between anxiety and depressive symptoms, particularly in this age group, the similarity of findings is not surprising but may suggest that both types of distress should be considered for most comprehensively identifying at-risk individuals. Relative to BMI, there was greater variation in anxiety and depressive symptoms across waves, whereby symptom levels of both increased until wave 4. The drop in symptoms at wave 4 was somewhat surprising. Important to note, however, is that we did not model mood trajectories per se. In fact, this pattern is consistent with other studies of changes in psychological distress during adolescence, which commonly find a subset of the population to be characterized as having early high levels of depressive symptoms which decline steadily after mid-adolescence [31–33]. Alternatively, the magnitude of the change may reflect more of a statistical artifact than a true effect. Regardless of the symptom changes, the associations of depressive and anxiety symptoms with baseline mean BMI persisted over time.

Both the method and findings of this study highlight key issues for future research. The stability of BMI over the adolescent period studied is striking. Limited change in BMI over this short period is consistent with the strong degree of autocorrelation found within BMI class trajectories. Studies using growth mixture modeling that have not also considered the autocorrelation structure of BMI within class trajectories may have yielded different models (i.e., different trajectory patterns) from those that would have been obtained if autocorrelation was modeled explicitly [11, 34]. In fact, when we evaluated models that ignored autocorrelation in these data, we found different patterns of class membership from

those reported here. Future studies using growth mixture modeling should explicitly accommodate within-class autocorrelation if present.

Within a growth mixture model framework, one could examine changes in BMI in relation to changes in anxiety and depression throughout the same period of study. This more complex question requires that several important analytic stages be addressed first, especially for GMMs. For example, patterns occurring in distress and BMI each need to be carefully examined. By developing the latent BMI trajectory class structure during adolescence and examining these in relation to anxiety and depression symptoms, this study provides a beginning to the process of answering that more complicated question. However, given the relatively static BMI levels throughout the study period, it is unlikely that an investigation of latent class trajectories for anxiety and depressive symptoms would reveal any different association with levels of BMI during the study period in the current sample. As a result, it may not be worth undertaking the more sophisticated investigation of latent class trajectories in BMI in relation to latent class trajectories of anxiety and depression within this cohort, because the BMI trajectories are relatively flat, hence there is no substantive change to evaluate. However, in other periods of the lifecourse, this may be a valuable approach though evaluating the individual variable trajectories initially would be a wise first step.

Although adolescence may not be the ideal developmental period for establishing whether depressive or anxiety symptoms affect development of overweight and obesity, whether it provides an effective or appropriate time for intervening on these processes remains to be determined. Significant changes in cognitive processes occur during puberty which may enable adolescents to benefit from cognitive behavioral interventions that were not efficacious in younger children. Our work suggests that even greater attention to specific forms of distress and how they develop over time might further enhance our understanding of the distress–weight status relationship and how best to intervene. Other work has distinguished subtypes of depression (or distress more generally) suggesting that they may provide greater insight into how distress influences weight status [35], although as yet, the developmental course of depression and when it resolves clearly into one subtype or another has not been fully established [36]. Studies have suggested that once obesity develops, it is difficult to treat [37], while others suggest that some children who are obese will, through normative growth changes, not maintain their obesity through adolescence [11]. This adds urgency to the need to disentangle the relationships between psychological distress and obesity among adolescents or younger children to inform development of effective prevention and intervention strategies.

There are a number of limitations to this study. There was a somewhat greater loss to follow-up among older subjects, but given the minimal change in BMI, this loss to follow-up is unlikely to alter our findings. Other limitations include measuring anxiety symptoms starting at wave 2, and having symptom measures of anxiety and depression only, with no information on mental health diagnoses. Further, we had only 3 years of follow-up data and by the very nature of growth mixture modeling, some latent classes (e.g., the severely obese class) are quite small and formal evaluation therein may be underpowered and the utility of formal significance testing was decreased.

Strengths of the study include a large community based sample with availability of repeated measures over time. In addition, the study includes validated measures of both depressive and anxiety symptoms, a range of potential confounders, as well as objective measures of weight and height which are less likely to be biased by psychological distress. The latent class analysis enabled separating our sample into homogenous subgroups empirically,

identifying relevant features of each latent class, and considering how these population subgroups relate to other exposures and outcomes.

In conclusion, in the present study, BMI class trajectories were largely stable; depressive and anxiety symptoms were associated with higher BMI and maintenance of BMI throughout the follow-up period. Perhaps somewhat surprisingly, although BMI is known to differ by gender and race/ethnicity, the relationships between psychological distress and BMI trajectory class membership do not appear to differ by these factors. Processes earlier in the lifecourse may need to be considered in order to determine fully whether psychological distress actually “leads” to greater weight gain, and how the social environment may influence vulnerability to developing high levels of distress, obesity, and unhealthy weight gain. Future work may separately want to consider whether adolescence could be an appropriate time for intervening on these processes.

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Fig. 1.

The five-class BMI trajectory class model and individual trajectory class coefficients (+SE). Estimated *N* for each class is: normal weight= 746.4, overweight=561.3, obese–overweight=56.9, obese=142.9, severely obese=20.4

Table 1

Distribution of BMI, depressive, and anxiety symptoms at first measurement by sample characteristics

	Mean (95% confidence interval)				
	Wave 1 N (%)	Age (years)	BMI	Depressive symptoms	Anxiety symptoms ^a
Total sample	1,528 (100)	14.4 (14.3, 15.4)	23.4 (23.1, 23.7)	13.7 (13.2, 14.1)	41.1 (40.6, 41.6)
Gender					
Male	745 (48.8)	14.5 (14.3, 14.6)	23.0 (22.6, 23.5)	12.3 (11.7, 12.9)	39.4 (38.8, 40.0)
Female	783 (51.2)	14.3 (14.2, 14.5)	23.7 (23.3, 24.1)	15.0 (14.3, 15.7)	42.8 (42.1, 43.5)
Race/ethnicity					
White	809 (52.9)	14.4 (14.3, 14.6)	22.5 (22.1, 22.8)	13.1 (12.4, 13.7)	40.9 (40.2, 41.5)
Black	719 (47.1)	14.4 (14.2, 14.5)	24.4 (23.9, 24.9)	14.3 (13.7, 15.0)	41.4 (40.7, 42.1)
Baseline pubertal status					
Prepubertal	154 (10.1)	11.6 (11.5, 11.8)	20.2 (19.5, 20.9)	11.8 (9.1, 14.5)	41.5 (39.6, 43.2)
Pubertal	597 (39.0)	13.2 (13.1, 13.4)	22.3 (21.9, 22.8)	13.7 (12.8, 14.5)	40.7 (40.0, 41.5)
Postpubertal	779 (50.9)	15.9 (15.8, 16.0)	24.8 (24.3, 25.2)	13.8 (13.2, 14.3)	41.4 (40.7, 42.0)
Parent's education					
High school	358 (23.4%)	14.2 (14.0, 14.5)	23.8 (23.2, 24.5)	15.5 (14.5, 16.5)	42.7 (41.7, 43.7)
Some college or vocational school	447 (29.3%)	14.3 (14.1, 14.5)	24.4 (23.8, 25.0)	14.0 (13.1, 14.8)	41.6 (40.8, 42.4)
College graduate	419 (27.4%)	14.4 (14.2, 14.6)	23.0 (22.4, 23.5)	13.5 (12.6, 14.5)	40.5 (39.5, 41.4)
Professional degree	304 (19.9%)	14.7 (14.4, 14.9)	21.9 (21.4, 22.4)	11.5 (10.6, 12.4)	39.6 (38.5, 40.7)

^a Anxiety was first measured at wave 2 by design (N=1,361). All other factors were first measured at wave 1

Table 2

Summary of model fit and BMI class trajectories for models assessing 2–11 latent classes

Class number	Model fit criterion ^a			AR(1) ^d	Trajectory direction ^b			
	df	–2LL ^c	AIC ^c	BIC ^c	Positive	Negative	U-shaped	Flat
2	15	22,916.2	22,946.2	23,026.2	0.944	2	0	0
3	21	22,692.4	22,734.4	22,846.3	0.923	3	0	0
4	26	22,613.6	22,665.6	22,804.3	0.873	4	0	0
5	31	22,561.9	22,623.9	22,789.2	0.842	4	0	1
6	36	22,522.8	22,594.8	22,786.8	0.850	5	0	1
7	41	22,499.2	22,581.2	22,799.8	0.805	5	0	1
8	46	22,472.1	22,564.1	22,809.3	0.733	6	0	1
9	51	22,450.7	22,552.7	22,824.6	0.734	6	0	2
10	56	22,432.0	22,544.0	22,842.6	0.742	6	0	2
11	61	22,414.4	22,536.4	22,861.6	0.742	6	1	2

^a Although bootstrap likelihood ratio tests indicated that the six-class model was the best fitting (–2LL diff=39.097, $df=5$, p value<0.001 for five-vs. six class, whereas seven vs. six class –2LL diff=23.670, $df=5$, p value=0.3636) the five-class model was chosen for parsimony and because the six-class model provided no improved interpretational difference

^b For a given direction, trajectories were parallel in all models tested

^c In general, decreases in these indices indicate better model fit. The –2 log likelihood (–2LL) will always improve with increasing model complexity up to a saturated model, so placing emphasis on model parsimony requires examination of the AIC and BIC. BIC is more conservative than AIC and may be preferable as a guide

^d AR(1) includes the autocorrelation of the residuals between successive measures and the autocorrelation among residuals between an individual parameterized trajectory and the class mean trajectory. Therefore, the larger the AR(1), the greater the consistency of individual parameterized trajectories above or below the class mean trajectory

Table 3

Class membership probabilities modeled in relation to sociodemographic factors

	Odds ratio (95% confidence interval)			
	BMI trajectory class			
	Overweight	Obese→overweight	Obese	Severely obese
White female	1.23 (0.91, 1.66)	1.32 (0.59, 2.95)	1.07 (0.60, 1.89)	2.32 (0.40, 13.33)
Black male	1.32 (0.96, 1.82)	1.87 (0.87, 4.04)	2.02 (1.20, 3.41)	5.24 (1.15, 23.89)
Black female	0.91 (0.31, 2.65)	1.04 (0.07, 15.18)	1.38 (0.22, 8.70)	1.84 (0.01, 399.74)
Age (1 year) male	0.91 (0.83, 1.00)	1.04 (0.83, 1.29)	1.07 (0.92, 1.24)	1.24 (0.88, 1.74)
Age (1 year) female	1.21 (0.73, 2.01)	1.30 (0.36, 4.77)	1.10 (0.45, 2.69)	2.33 (0.18, 30.55)
Peripubertal	0.87 (0.63, 1.19)	0.89 (0.42, 1.91)	0.74 (0.44, 1.26)	1.06 (0.30, 3.69)
Prepubertal	0.68 (0.40, 1.16)	0.48 (0.11, 2.08)	0.88 (0.37, 2.10)	–
College graduate	1.27 (0.92, 1.76)	2.36 (0.88, 6.30)	2.14 (1.09, 4.18)	0.98 (0.08, 11.82)
Some college or vocational	1.67 (1.20, 2.31)	2.97 (1.12, 7.92)	3.35 (1.74, 6.44)	8.00 (1.10, 58.05)
High school or less	1.53 (1.08, 2.16)	3.27 (1.21, 8.84)	3.39 (1.73, 6.62)	5.01 (0.64, 39.45)

Reference for sociodemographic factors: White male, 14.4 years at baseline, postpubertal at baseline, parental professional degree, BMI trajectory class=normal weight. Because there were no prepubertal subjects assigned to the severely obese class, this cell is left blank

Table 4
Mean (95% CI) depressive and anxiety symptoms of the cohort and five BMI trajectory classes

	N (%)	BMI trajectory class				
		Normal weight	Overweight	Obese→overweight	Obese	Severely obese
Depressive Sx W1 ^a	1,168 (97.6)	13.4 (12.6, 14.2)	13.6 (12.7, 14.4)	14.7 (11.3, 18.1)	14.7 (12.9, 16.4)	15 (11.7, 18.3)
Depressive Sx W2 ^b	1,359 (99.3)	12.0 (11.2, 12.7)	13.5 (12.5, 14.4)	14.4 (10.6, 18.2)	15.1 (13.0, 17.1)	17.6 (11.5, 23.7)
Depressive Sx W3	1,418 (92.8)	14.2 (13.4, 14.9)	15.8 (14.9, 16.8)	16.9 (13.3, 20.6)	17.2 (15.3, 19.1)	18.7 (13.6, 23.8)
Depressive Sx W4	1,308 (85.6)	7.4 (6.8, 8.0)	8.6 (7.8, 9.4)	8.7 (5.9, 11.4)	10.1 (8.4, 11.8)	9.0 (5.3, 12.7)
Anxiety Sx W2 ^b	1,361 (89.1)	40.2 (39.5, 41.0)	41.5 (40.6, 42.4)	42.5 (39.3, 45.7)	43.1 (41.3, 44.8)	45.1 (41.5, 48.6)
Anxiety Sx W3	1,418 (92.8)	40.1 (39.4, 40.8)	41.6 (40.8, 42.5)	41.6 (38.7, 44.4)	42.7 (41.2, 44.2)	42.1 (38.8, 45.3)
Anxiety Sx W4	1,308 (85.6)	39.3 (38.5, 40.0)	40.7 (39.8, 41.5)	41.6 (38.4, 44.9)	41.7 (40.0, 43.4)	40.1 (36.2, 44.0)

^aNot measured on initial fifth to sixth graders

^bNot measured on initial fifth graders

Table 5

Class membership probabilities modeled in relation to depression and anxiety at each wave

		Odds ratio (95% confidence interval)				
		BMI trajectory class^a				
	Eligible N	N (%)	Overweight	Obese→overweight	Obese	Severely obese
Depression (per 9.37 difference in scale score)						
Wave 1	1,196	1,168 (97.6)	0.99 (0.85, 1.15)	1.12 (0.79, 1.58)	1.10 (0.87, 1.38)	1.06 (0.63, 1.78)
Wave 2	1,386	1,337 (96.4)	1.14 (1.01, 1.29)	1.23 (0.94, 1.62)	1.28 (1.06, 1.53)	1.52 (1.02, 2.25)
Wave 3	1,528	1,370 (89.7)	1.15 (1.03, 1.28)	1.26 (0.97, 1.63)	1.27 (1.06, 1.51)	1.43 (0.95, 2.17)
Wave 4	1,528	1,285 (84.1)	1.16 (0.98, 1.36)	1.15 (0.78, 1.70)	1.47 (1.15, 1.88)	1.23 (0.67, 2.27)
Anxiety (per 6.69 difference in scale score)						
Wave 2	1,386	1,337 (96.4)	1.13 (1.01, 1.28)	1.23 (0.92, 1.63)	1.30 (1.07, 1.57)	1.56 (1.01, 2.43)
Wave 3	1,528	1,370 (89.7)	1.18 (1.05, 1.34)	1.14 (0.84, 1.54)	1.33 (1.08, 1.62)	1.17 (0.71, 1.92)
Wave 4	1,528	1,285 (84.1)	1.15 (1.01, 1.30)	1.28 (0.94, 1.74)	1.29 (1.05, 1.59)	1.04 (0.63, 1.70)

All models adjusted simultaneously for age, gender, race, pubertal status, and parental education

^aNormal weight is the reference BMI trajectory class