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In, out, and fluctuating: obesity from adolescence to adulthood

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ABSTRACT

Purpose: While high levels of obesity prevalence and incidence have been well documented, there is less research on obesity dynamics over time. In this article, we sought to understand the body mass index (BMI) trajectories in and out of obesity from adolescence to adulthood.
Methods: We used the National Longitudinal Study of Adolescent to Adult Health to explore American obesity dynamics from mean ages 15–28 years. We analyzed six BMI trajectories from 1994 to 2008 and examined their contextual sociodemographic correlates using ordinal logistic regression models.
Results: More than 50% of adolescents with normal BMI moved to overweight/obesity by adulthood; only 8% of overweight and 2% of obese adolescents achieved normal BMI in adulthood. While some sociodemographic characteristics such as sex, race/ethnicity, place of residence, and parents' education were associated with being in certain BMI trajectories among adolescents with normal BMI, they were not so associated among adolescents starting at obesity.
Conclusions: Transitioning to higher BMI categories was common, whereas the opposite direction was rare. Pathways to obesity prevention might be easier to identify than those to reversal, as contextual factors had more explanatory power for youths with normal BMI than for those with obese BMI.

Purpose

It has been well established that body mass index (BMI) tends to track over the long-term [1–13]. Because elevated BMI is a risk factor for many adverse health conditions [14,15], its current level could set the stage for health in the long run. Research has shown that habits and behaviors are strongly associated with BMI [16–20]. Thus, the period from adolescence to adulthood, a time when habits and behaviors with lasting health implications are potentially still malleable, can be particularly critical for health over the long term. While studies have examined obesity incidence, and to a lesser extent, obesity reversal, during this stage of the life course, fluctuations in and out of obesity have not been explicitly considered. BMI categories are not absorbing states from which people cannot exit, so it is crucial to consider them at not only one or two discrete time points, but their dynamics over time.

Certain population subgroups have been found to have higher risk of obesity at any given point in time. For example, women and people of color have been identified as more vulnerable to obesity at most ages [21,22]. There are also differences in obesity measures by other contextual characteristics, such as socioeconomic status and urbanicity [22–24]. To enhance our understanding of patterns of obesity dynamics, we used the National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally representative cohort of Americans followed from their young teenage years in 1994–1995 to around 30 years of age in 2008. We defined and analyzed various pathways that people could take in and out of obesity in this critical life stage, and identified sociodemographic characteristics associated with these trajectories.

Moreover, the trajectories to obesity begin early in life and those who are obese in adolescence might already be fundamentally different from those who are not with respect to sociodemographic characteristics [25,26]. Consequently, their long-term BMI dynamics might differ. Therefore, we examined their subsequent BMI progression separately. Once trajectories are stratified by adolescent BMI status, are sociodemographic characteristics similarly or differently associated with certain trajectories within the various strata?

Methods

Add Health is a nationally representative longitudinal study of adolescents in grades seven through twelve in the United States in

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1994–1995. Almost 21,000 adolescents were interviewed at wave I, and three follow-up waves were conducted through 2008. Wave II, by design, was a subsample of wave I and excluded those already in the twelfth grade at wave I. The mean ages of the cohort were 15, 16, 22, and 28 years at these four waves.

At the first wave of Add Health, height and weight were self-reported; at all subsequent waves, height and weight were additionally measured by interviewers. BMI was calculated in kg/m^2, with self-reported data for wave I and measured data for waves II through IV. Heights of seven feet or taller, weights of 700 pounds and heavier, and BMI values less than 10 kg/m^2 or greater than 75 kg/m^2 were considered biologically implausible and coded as missing. These constituted a very small proportion of the sample.

Age-appropriate classifications of BMI category were used. In line with clinical recommendations, we used BMI z-scores for age and sex, calculated with reference to the Centers for Disease Control and Prevention growth curves, for adolescents under age 18 years. Overweight was defined as a BMI z-score greater than or equal to 85th percentile and less than 95th percentile and obesity as a BMI z-score greater than or equal to 95th percentile. For adults, we used BMI values of BMI greater than or equal to 25 kg/m^2 and less than 30 kg/m^2 for overweight and BMI greater than or equal to 30 kg/m^2 for obesity [27,28]. All others values were coded as a normal BMI.

Sociodemographic covariates from the baseline were used to track BMI trajectories according to contextual adolescent characteristics. These included sex (men = reference, women), race (non-Hispanic white = reference, non-Hispanic black, Hispanic, Asian, other), place of residence (rural = reference, suburban, urban), and coresiding parents' education (no coresiding parent graduated from college = reference, one coresiding parent graduated from college, both coresiding parents graduated from college). Information on parents' education was collected from an adolescent's parent (preferably the resident mother) by asking “How far did you go in school?” and “How far did your current (spouse/partner) go in school?” Even though the current spouse/partner might not have been the respondent's biological parent, this person was in the household with the respondent at the baseline.

We first looked at mean BMI at each wave and calculated the likelihood of experiencing various transitions between the BMI categories of normal, overweight, and obese, conditional on the starting state. Looking at shifts across BMI categories between consecutive waves allowed us to zero in on shorter windows within the period from adolescence to adulthood.

We then analyzed trajectories across the four data waves from adolescence to adulthood. Because obesity is more strongly linked with adverse health outcomes than overweight [29], we focused on this more severe form of adiposity and combined the normal and overweight categories in the following analyses of trajectories. Those with anthropometric data at all four waves were classified into six mutually exclusive and exhaustive groups as follow (see Table 1):

(1) Not obese at all four waves: most healthy BMI trajectory from adolescence to adulthood.
(2) Not obese at wave I but made exactly one upward transition into obesity status by wave IV: healthy BMI in adolescence but became obese for the long-term.
(3) Not obese at wave I and fluctuated at least twice between not obese and obese across waves: healthy BMI in adolescence but fluctuated thereafter.
(4) Stayed obese throughout all four waves: least healthy BMI trajectory from adolescence to adulthood.
(5) Obese at wave I but made exactly one downward transition into normal status by wave IV: unhealthy BMI in adolescence that achieved healthy BMI in adulthood.
(6) Obese at wave I and fluctuated at least twice between obese and not obese across waves: unhealthy BMI in adolescence but fluctuated thereafter.

Note that study subjects in groups (3) and (6), those with fluctuations across data waves, could end up obese or nonobese at wave IV. They likely oscillated around the obesity threshold, and were probably similar regardless of their BMI category at wave IV.

For the three trajectory groups that were not obese at the baseline, there was a natural ordering of groups based on expected severity—stayed not obese, not obese and fluctuating, and not obese to obese without reverting. Similarly, for the three trajectory groups that were obese at the baseline—obese to not obese without reverting, obese and fluctuating, and stayed obese. We calculated the proportion in each of these BMI trajectory groups and the mean BMI at each wave for each of these groups.

We estimated two ordinal multivariate logistic regressions, one using as dependent variable BMI trajectory groups for those who were not obese at the baseline, and the other using as dependent variable BMI trajectory groups for those who were obese at the baseline. The sociodemographic characteristics described previously were included as explanatory variables to investigate which subgroups were associated with more or less severe BMI trajectories. For each of these two sets of dependent variables, Brant tests indicated that the proportional odds assumption was not violated.

Table 1
All possible obesity dynamics and their BMI trajectory groups

BMI trajectory group	Wave I	Wave II	Wave III	Wave IV
(1) Stayed not obese throughout the waves	Not obese	Not obese	Not obese	Not obese
(2) Started not obese and became obese without reverting to not obese	Not obese	Obese	Obese	Obese
	Not obese	Not obese	Obese	Obese
	Not obese	Not obese	Not obese	Obese
(3) Started not obese and fluctuated	Not obese	Not obese	Obese	Not obese
	Not obese	Obese	Not obese	Not obese
	Not obese	Obese	Not obese	Obese
	Not obese	Obese	Obese	Not obese
(4) Stayed obese throughout the waves	Obese	Obese	Obese	Obese
(5) Started obese and became not obese without reverting to obese	Obese	Not obese	Not obese	Not obese
	Obese	Obese	Not obese	Not obese
	Obese	Obese	Obese	Not obese
(6) Started obese and fluctuated	Obese	Obese	Not obese	Obese
	Obese	Not obese	Obese	Obese
	Obese	Not obese	Obese	Not obese
	Obese	Not obese	Not obese	Obese

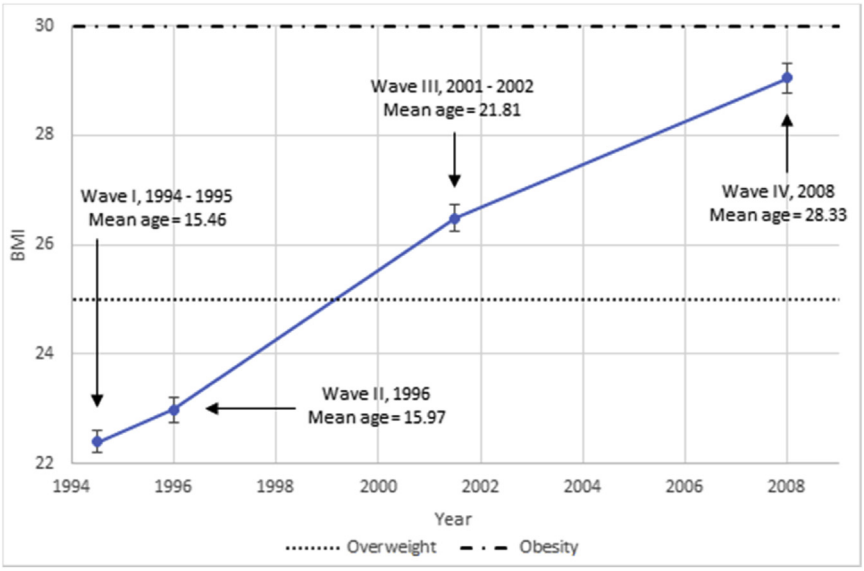

Fig. 1. Mean BMI (with 95% confidence intervals) across waves I to IV (mean ages 15–28 years). Sample sizes for waves I through IV were 18,416, 13,367, 13,535, and 14,562, respectively. The adulthood overweight (25 kg/m^2) and obesity (30 kg/m^2) thresholds are denoted with the horizontal lines. Data: National Longitudinal Study of Adolescent to Adult Health.

To account for the complex survey design of Add Health, we used cross-sectional survey weights and longitudinal survey weights, as appropriate [30]. Analyses were performed in Stata 15.1 [31].

Results

Figure 1 illustrates population-level BMI, which steadily increased as the cohort aged from mean ages 15–28 years between 1994–1995 and 2008.

From the increase in mean BMI over time, it would be expected that people transitioned into higher BMI categories over this period. Table 2 shows the empirical probabilities (in percentages) of BMI transitions over the entire period and between consecutive waves. In the table, we distinguished between normal and overweight within the nonobese category to provide more detail.

From adolescence to adulthood, 46% of people who had a normal BMI at the baseline maintained that status; this entails that a majority transitioned upward to overweight or obesity. Meanwhile, only 8% of overweight adolescents and 2% of obese adolescents made downward transitions to normal BMI status in the same 15-year period.

Aside from waves I to II (mean ages 15 to 16), there were about six years between consecutive waves. Across these consecutive six-

Table 2
Percentage experiencing each BMI transition between waves I and IV (mean ages 15 and 28 years) and between consecutive waves, conditional on starting BMI category

(n = 9043)		Wave IV (mean age 28) BMI category		
		Normal	Overweight	Obese
Wave I (mean age 15) BMI category	Normal	45.63	32.78	21.59
	Overweight	8.11	24.36	67.52
	Obese	1.81	9.68	88.51
(n = 9040)		Wave II (mean age 16) BMI category		
		Normal	Overweight	Obese
Wave I (mean age 15) BMI category	Normal	91.58	7.47	0.95
	Overweight	26.06	51.74	22.19
	Obese	6.12	15.84	78.05
(n = 8824)		Wave III (mean age 22) BMI category		
		Normal	Overweight	Obese
Wave II (mean age 16) BMI category	Normal	66.02	26.09	7.89
	Overweight	14.17	39.39	46.44
	Obese	3.02	14.02	82.96
(n = 8861)		Wave IV (mean age 28) BMI category		
		Normal	Overweight	Obese
Wave III (mean age 22) BMI category	Normal	62.82	29.68	7.50
	Overweight	11.75	46.04	42.21
	Obese	1.61	8.95	89.44

Sample sizes differ because only common observations between the two waves of interest were used.
Data: National Longitudinal Study of Adolescent to Adult Health.

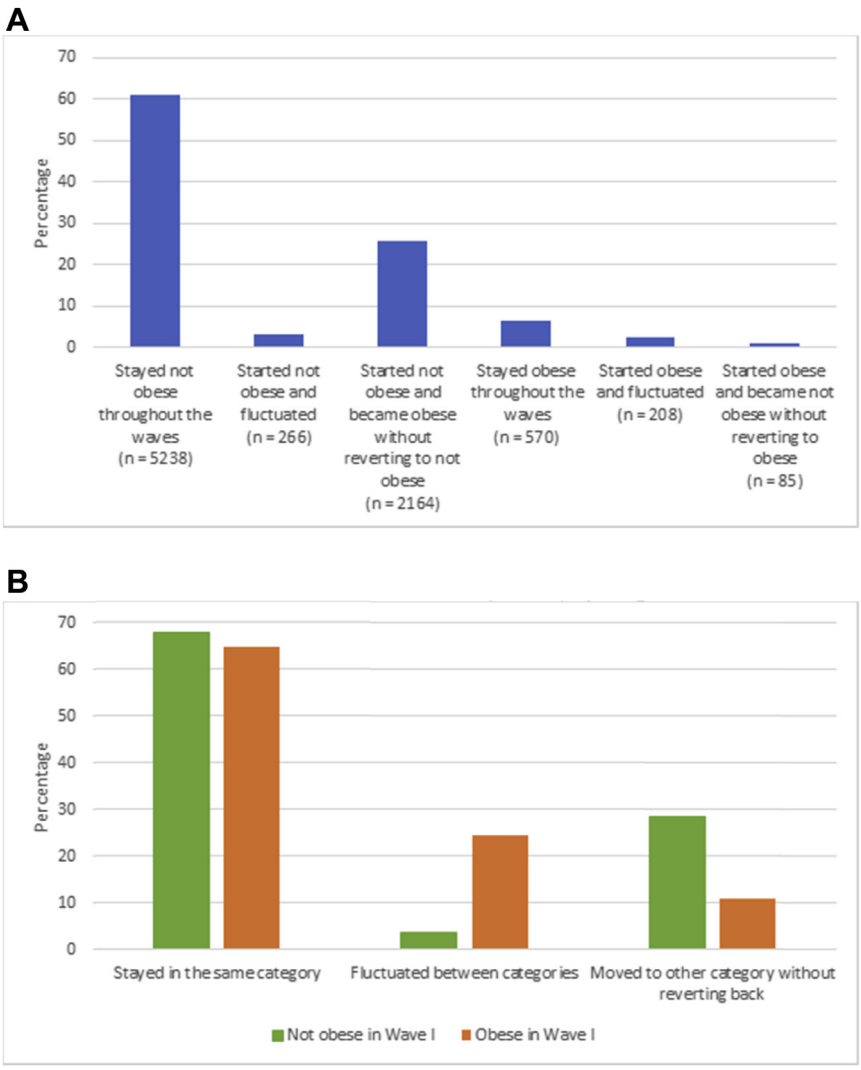

Fig. 2. BMI trajectory groups between waves I and IV (mean ages 15 and 28 years), overall and conditional on BMI category in wave I. (A) Percentage of people in each BMI trajectory group. (B) Percentage of people in each BMI trajectory group, conditional on BMI category at wave I. Data: National Longitudinal Study of Adolescent to Adult Health.

year periods, people were most likely to stay in the same BMI category and were least likely to move to a lower category. However, those who were overweight had similar chances of staying overweight or of becoming obese. Even though the percentage of people who moved upward to a higher BMI category between any two consecutive waves was never particularly high, most of the cohort eventually moved to a higher BMI category over the course of 15 years.

There are several trajectories in and out of obesity, and it is important to understand how such a large proportion of young adults ended up with elevated levels of BMI. Figure 2 depicts the distribution of the cohort across our six defined BMI trajectories.

Around 60% of the cohort stayed not obese throughout the waves and the next largest group at about 25% was started not obese and became obese without reverting back (Fig. 2A). Conditional on BMI category at mean age 15 years (Fig. 2B), the majority stayed in the same category (around 65% for both groups). Among those who were not obese at the baseline, becoming obese was more common than fluctuating across BMI categories (30% vs. 5%). On the contrary, among those who were obese at the baseline, fluctuating across BMI categories was more common than becoming not obese (25% vs. 10%).

Figure 3 displays the mean BMI at each wave for the six BMI trajectory groups. This is akin to Figure 1, but demonstrates the mean BMI pathways that the different trajectory groups took over the course of almost 15 years.

By definition, the BMI trajectory groups that started not obese at the baseline had lower starting mean BMIs than the BMI trajectory groups that started obese. Those starting not obese continued to have lower mean BMI at wave II (mean age 16 years) than those starting obese, but the curves began to overlap by wave III (mean age 22 years). By wave IV (mean age 28 years), the ordering of lowest to highest mean BMI among the six groups was as follows—stayed not obese throughout the waves, started obese and became not obese without reverting to obese, started not obese and fluctuated, started not obese and became obese without reverting to not obese, started obese and fluctuated, and stayed obese throughout the waves. By mean age 28 years, those who stayed obese throughout the waves had an average BMI over 40 kg/m^2, the threshold for severe obesity.

Next, we explored associations between sociodemographic characteristics and BMI trajectories from adolescence to adulthood. The odds ratios from ordinal logistic regressions for those who were not obese at the baseline and for those who were obese at the baseline are presented in Table 3.

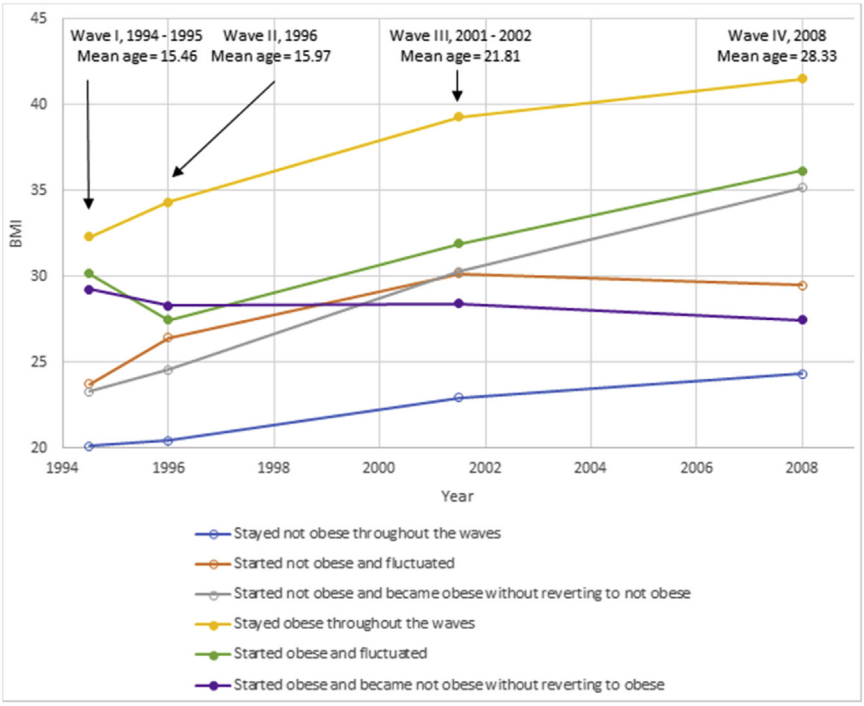

Fig. 3. Mean BMI across waves I to IV (mean ages 15–28 years) by BMI trajectory group. The "started obese and became not obese without fluctuations" curve (in purple) began at a mean BMI under 30 kg/m^2, the adult threshold for obesity, but were classified as obese according to BMI z-scores, as appropriate for their age. For those under 18 years of age, obesity was defined based on sex and age reference curves for adolescents, not the threshold of 30. Data: National Longitudinal Study of Adolescent to Adult Health. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

In the model for those started off as not obese (column 1), the BMI trajectory groups were ranked from least to most severe, giving the ordering of the ordinal-dependent variable from low to high as follows: staying not obese, fluctuating, and becoming obese without reverting to nonobese. Among those who were not obese when first observed in adolescence, women were more likely to be in a higher BMI trajectory group than men, non-Hispanic blacks and Hispanics were more likely to be in a higher trajectory group than non-Hispanic whites, suburban residents were less likely to be in a higher trajectory group than rural residents, and those with more coresiding educated parents were less likely to be in a higher trajectory group than those who had no coresiding parent who graduate from college.

In the model for those who started off as obese (column 2), the ordering of categories from low to high was becoming not obese without reverting to obese, fluctuating, and staying obese, again ranking the BMI trajectory groups from least to most severe. Among those who were obese when first observed in adolescence, none of

Table 3
Odds ratios from ordinal logistic regressions of BMI trajectory groups between waves I and IV (mean ages 15 and 28 years), conditional on obesity status at the baseline

Variable	(1) Not obese BMI category in wave I (mean age 15 years) (n = 7331)	(2) Obese BMI category in wave I (mean age 15 years) (n = 817)
	Odds ratio (95% CI)	Odds ratio (95% CI)
Sex (reference = men)		
Women	1.206 (1.053, 1.382)	1.502 (1.000, 2.256)
Race (reference = non-Hispanic white)		
Non-Hispanic black	1.354 (1.143, 1.604)	0.980 (0.651, 1.475)
Hispanic	1.244 (1.002, 1.544)	0.818 (0.514, 1.301)
Asian	0.738 (0.493, 1.106)	2.015 (0.824, 4.925)
Other	1.124 (0.821, 1.540)	1.104 (0.478, 2.550)
Place of residence (reference = rural)		
Suburban	0.847 (0.720, 0.996)	0.897 (0.537, 1.499)
Urban	1.001 (0.838, 1.196)	1.076 (0.717, 1.616)
Parents' education (reference = no co-residing parent graduated from college)		
One coresiding parent graduated from college	0.812 (0.685, 0.962)	0.845 (0.478, 1.494)
Two coresiding parents graduated from college	0.564 (0.451, 0.706)	0.606 (0.264, 1.392)

Categories from lowest to highest among those who started out not obese: stayed not obese throughout the waves, started not obese and fluctuated, started not obese and became obese without reverting to not obese.
Categories from lowest to highest among those who started out obese: started obese and became not obese without reverting to obese, started obese and fluctuated, stayed obese throughout the waves.
CI, confidence interval.
Data: National Longitudinal Study of Adolescent to Adult Health.

the sociodemographic characteristics were significantly associated with BMI trajectory. Thus, while personal characteristics (sex and race) and contextual characteristics (place of residence and parents' education) were associated with the likelihood of changing BMI category among adolescents with normal BMI, they were not associated with the likelihood of being in certain BMI trajectories among adolescents with obese BMI.

Conclusions

This study explored BMI trajectories during the developmentally important period from adolescence to adulthood following a U.S. cohort of today's adults over a period of 15 years. The mean BMI of the cohort increased as they progressed into adulthood. Fewer than 50% of people who had a normal BMI in adolescence still had a normal BMI by adulthood, suggesting that upward movement in BMI status occurred for most people. Furthermore, only 8% of overweight adolescents and 2% of obese adolescents fell to a normal BMI in adulthood. These patterns are consistent with previous studies of this cohort [7,13].

To explore obesity dynamics, we combined normal and overweight into one category and compared the BMI trajectories of adolescents who were and were not obese at wave I (mean age 15). The most commonly followed BMI trajectory was to stay in the not obese category. Among those who were not obese as adolescents, becoming obese was more common than fluctuating; among those who were obese at the baseline, fluctuating was more common than becoming not obese. That is, people starting not obese and transitioning upward were unlikely to come back down. For people starting obese, even if they transitioned downward at some point, they tended to go back up again instead of maintaining healthier levels of body mass, demonstrating the "sticky" state of obesity and the difficulty of sustained weight loss [32–34].

Among those who were not obese at the baseline, women, non-Hispanic blacks and Hispanics, rural and urban (compared with suburban) residents, and those with fewer coresiding parents with a college education were more likely to be in higher trajectory groups, that is, more likely to fluctuate or become obese than to remain not obese. These characteristics are consistent with previous studies on obesity risk [21–24]. By contrast, these characteristics were not associated with the BMI trajectories of youths who were obese at the baseline. That is, while there seem to be some not obese adolescent subgroups that could be considered for obesity prevention, our study did not identify obese adolescent subgroups for obesity management or reversal. This again indicates that obesity is a sticky state.

Another possible reason resulting in the various characteristics having no significant association with the BMI trajectories of youths who were obese at the baseline was the relatively small size of the obese group. As a sensitivity check, the BMI classifications were instead split between normal versus overweight or obese; this approach has the advantage of having a larger sample starting off in the heavier category ($n = 2013$) versus the lighter category ($n = 6135$). Results from ordinal logistic models were generally consistent with those shown previously. An exception is that women with normal BMI in adolescence were less likely to be in higher trajectory groups than men, whereas women with overweight/obese BMI at adolescence were more likely to be in higher trajectory groups than men. These patterns may point to potential nuances in the differences in the overweight category between men and women.

In addition, although Brant tests did not reject the proportional odds assumption for our ordinal logistic regression models, we also relaxed this assumption and ran multinomial logistic regression models for our trajectory groups conditional on baseline classification. Significance conclusions and magnitudes of the estimates were similar in corresponding models in this robustness check.

There are a few limitations to these analyses. First, information on pregnancy status was not consistently asked across the waves of Add Health, so some women might have had an overestimated BMI at some data points, thus increasing the likelihood of women being in more severe BMI trajectories than men. Second, we might not have observed all BMI fluctuations, as survey waves were conducted at discrete time points. Not observing some fluctuations decreased the likelihood of being in the fluctuating groups. Third, we classified adolescents and adults into BMI categories based on age-appropriate, but differing, classification schemes. Therefore, there could be a discontinuity between the two classification schemes. This is a challenge for all studies examining BMI patterns across the transition to adulthood, and future research should explore techniques for modeling this transition.

While there are national estimates on the prevalence of obesity and studies documenting the characteristics associated with obesity, less is known about its dynamics in the years from adolescence to adulthood. Obesity has long-term social, economic, and health implications, and a better understanding of its dynamics will help us understand how these implications play out. In an effort to explore such dynamics in this critical period, we analyzed BMI trajectories across 15 years of a nationally representative longitudinal survey of adolescent and adult health. The results presented here show that transitioning to higher BMI categories is common, and transitioning to lower BMI categories is rare. These findings emphasize the importance of prevention. Pathways to prevention may be easier to identify than those to reversal, as contextual factors had more explanatory power in explaining likelihood of being in certain BMI trajectory groups among youths with normal BMI than among youth with obese BMI. Further research is necessary to identify the sociodemographic subgroups for which targeted interventions in adolescence could potentially be directed for obesity management and reversal.

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References

[1] Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T. Do obese children become obese adults? A review of the literature. Prev Med 1993;22(2):167–77.
[2] Herman KM, Craig CL, Gauvin L, Katzmarzyk PT. Tracking of obesity and physical activity from childhood to adulthood: the physical activity longitudinal study. Int J Pediatr Obes 2009;4(4):281–8.
[3] Magarey AM, Daniels LA, Boulton TJ, Cockington RA. Predicting obesity in early adulthood from childhood and parental obesity. Int J Obes Relat Metab Disord 2003;27(4):505–13.

[4] Stettler N, Zemel BS, Kumanyika S, Stallings VA. Infant weight gain and childhood overweight status in a multicenter, cohort study. Pediatrics 2002;109(2):194–9.
[5] Cunningham SA, Kramer MR, Narayan KM. Incidence of childhood obesity in the United States. N Engl J Med 2014;370(5):403–11.
[6] Li C, Goran MI, Kaur H, Nollen N, Ahluwalia JS. Developmental trajectories of overweight during childhood: role of early life factors. Obesity (Silver Spring) 2007;15(3):760–71.
[7] Gordon-Larsen P, Adair LS, Nelson MC, Popkin BM. Five-year obesity incidence in the transition period between adolescence and adulthood: the national longitudinal study of adolescent health. Am J Clin Nutr 2004;80(3):569–75.
[8] Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. Obes Rev 2016;17(2):95–107.
[9] Cunningham SA, Datar A, Narayan KMV, Kramer MR. Entrenched obesity in childhood: findings from a national cohort study. Ann Epidemiol 2017;27(7):435–41.
[10] Smego A, Woo JG, Klein J, Suh C, Bansal D, Bliss S, et al. High Body Mass Index in Infancy May Predict Severe Obesity in Early Childhood. J Pediatr 2017;183:87–93.e1.
[11] Ryder JR, Jacobs Jr DR, Sinaiko AR, Kornblum AP, Steinberger J. Longitudinal Changes in Weight Status from Childhood and Adolescence to Adulthood. J Pediatr 2019;241:187–192.e2.
[12] Ward ZJ, Long MW, Resch SC, Giles CM, Cradock AL, Gortmaker SL. Simulation of growth trajectories of childhood obesity into adulthood. N Engl J Med 2017;377(22):2145–53.
[13] Gordon-Larsen P, The NS, Adair LS. Longitudinal trends in obesity in the United States from adolescence to the third decade of life. Obesity 2010;18(9):1801–4.
[14] Pi-Sunyer FX. Health implications of obesity. Am J Clin Nutr 1991;53(6 Suppl):1595S–603S.
[15] Wyatt SB, Winters KP, Dubbert PM. Overweight and obesity: Prevalence, consequences, and causes of a growing public health problem. Am J Med Sci 2006;331(4):166–74.
[16] Garaulet M, Ortega FB, Ruiz JR, Rey-López JP, Béghin L, Manios Y, et al. Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. Int J Obes (Lond) 2011;35(10):1308–17.
[17] Giammattei J, Blix G, Marshak HH, Wollitzer AO, Pettitt DJ. Television watching and soft drink consumption: associations with obesity in 11- to 13-year-old schoolchildren. Arch Pediatr Adolesc Med 2003;157(9):882–6.
[18] Boumtje PI, Huang CL, Lee J-Y, Lin B-H. Dietary habits, demographics, and the development of overweight and obesity among children in the United States. Food Policy 2005;30(2):115–28.
[19] Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Relationship between lifestyle behaviors and obesity in children ages 9-11: Results from a 12-country study. Obesity (Silver Spring) 2015;23(8):1696–702.
[20] Wilkie HJ, Standage M, Gillison FB, Cumming SP, Katzmarzyk PT. Multiple lifestyle behaviours and overweight and obesity among children aged 9-11 years: results from the UK site of the International Study of Childhood Obesity, Lifestyle and the Environment. BMJ Open 2016;6(2):e010677.
[21] Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. NCHS Data Brief 2017:1–8.
[22] Wang Y, Beydoun MA. The obesity epidemic in the United States - Gender, age, socioeconomic, Racial/Ethnic, and geographic characteristics: A systematic review and meta-regression analysis. Epidemiol Rev 2007;29:6–28.
[23] Befort CA, Nazir N, Perri MG. Prevalence of obesity among adults from rural and urban areas of the United States: findings from NHANES (2005-2008). J Rural Health 2012;28(4):392–7.
[24] Hill JL, You W, Zoellner JM. Disparities in obesity among rural and urban residents in a health disparate region. BMC Public Health 2014;14:1051.
[25] Singh GK, Kogan MD, Van Dyck PC, Siahpush M. Racial/ethnic, socioeconomic, and behavioral determinants of childhood and adolescent obesity in the United States: Analyzing independent and joint associations. Ann Epidemiol 2008;18(9):682–95.
[26] Troiano RP, Flegal KM. Overweight children and adolescents: Description, epidemiology, and demographics. Pediatrics 1998;101(3):497–504.
[27] Vidmar S, Cole T. Standardizing anthropometric measures inchildren and adolescents with new functions foregen. Stata J 2004;4(1):50–5.
[28] Nuttall FQ. Body mass index: obesity, bmi, and health: a critical review. Nutr Today 2015;50(3):117–28.
[29] Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories a systematic review and meta-analysis. JAMA 2013;309(1):71–82.
[30] Chen P, Chantala K. Guidelines for Analyzing Add Health Data. University of North Carolina at Chapel Hill, Carolina Population Center; 2014. https://www.cpc.unc.edu/projects/addhealth/documentation/guides/wt_guidelines_2016_1213.pdf. [Accessed 15 March 2019].
[31] StataCorp. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC; 2017. https://www.stata.com/support/faqs/resources/citing-software-documentation-faqs/.
[32] Jeffery RW, Drewnowski A, Epstein LH, Stunkard AJ, Wilson GT, Wing RR, et al. Long-term maintenance of weight loss: Current status. Health Psychol 2000;19(1):5–16.
[33] Kassirer JP, Angell M. Losing weight - An ill-fated new year's resolution. N Engl J Med 1998;338(1):52–4.
[34] Rothblum ED. Slim chance for permanent weight loss. Arch Sci Psychol 2018;6(1):63–9.