Depression, Antidepressant Use and Weight Gain*

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Abstract: We examine the joint effect of diagnosed depression and antidepressant use on body weight in a nationally representative sample of young adults in the United States. We employ a first-difference model that accounts for individual-level time-invariant unobservables. We find that depression with antidepressant use could increase the Body Mass Index by about 1 point and the probability of becoming overweight or obese by about 9.2 percentage points. The effect is larger for the unmarried and individuals with relatively low socioeconomic status. Next, we aim at isolating the effect of antidepressant use by controlling for depression symptoms and find that the increase in body weight is driven mainly by the use of antidepressants, not depression. Our results suggest that population-level increases in depression and antidepressant use among young adults in the United States could explain at least 1.5 percent of the increase in the obesity rate over the past two decades.

Key words: Obesity, body weight, BMI, depression, antidepressants

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1. Introduction

The prevalence of obesity is considered one of the most burdensome health problems in the developed world. In the United States, obesity rates have risen significantly over the past four decades from 13.4 percent in the early 1960s to 34.3 percent in 2007-08 (Ogden and Carroll, 2010). Obesity is found to be associated with several health problems such as cardiovascular disease and diabetes. Furthermore, it could contribute to approximately 16 percent of total healthcare spending in the United States (Cawley and Meyerhoefer, 2012).

A series of studies about the causes of the rapid increase in obesity rates have proposed multiple hypotheses. Among these are the roles of several economic and behavioral factors such as prices of and access to high-fat fast food, food advertising, physical activity, and technological change (Chou et al, 2004; Inas, 2006; Chou et al, 2008; Lakdawalla and Philipson, 2009; Powell and Chaloupka, 2009; Currie et al, 2010; Offer et al, 2010; Andreyeva et al, 2011), and also the role of emotional health (Tucker and Earl, 2010). Moreover, some studies find that the increase in the likelihood of becoming obese is associated with less smoking and higher cigarette prices (e.g. Chou et al, 2004). However, other studies find opposite or mixed results (Courtemanche, 2009; Wehby et al, 2012; Wehby and Courtemanche, 2012). These previous studies have found that economic and behavioral factors overall explain only a small proportion of the variation in body mass index (BMI) and obesity in the population (less than 10 percent — e.g. Chou et al, 2004),

suggesting that other factors play an important role in obesity, such as genetic factors, which have been supported in twin studies (Watson et al, 2006; Hjelmborg et al, 2008).

Another trend in population health that is similar and possibly related to the obesity trend is the increasing prevalence of depression and use of antidepressants over the past two decades. Currently, nearly 10 percent of adults in the United States have some form of depression (CDC, 2011a). The rates are highest among young adults 18–24 years of age (11.1%) and are slightly higher (10.2% versus 8%) among females than males (CDC, 2011b). Previous studies suggest a life-time prevalence of major depression of up to 5.2 percent in the 1980s, and up to 13.2 percent in 2001–02 (Hasin et al, 2005). Although some of the variation may be due to differences in measurements and samples, the upward trend could be corroborated by other upward trends in the treatment of depression and use of antidepressants. For example, the percentages of individuals seeking outpatient care for depression in the United States were 0.73 percent, 2.33 percent, and 2.88 percent in 1987, 1997, and 2007, respectively (Olfson et al, 2002; Marcus and Olfson, 2010). Furthermore, the rate of antidepressant use among patients receiving outpatient care for depression increased from 37 percent in 1987 to 73.8 percent in 1997, and was 75.3 percent in 2007 (Olfson et al, 2002; Marcus and Olfson, 2010).

Antidepressant use may cause weight gain and increase the likelihood of obesity through several pathways such as increasing appetite and lowering the metabolic rate (Fernstrom and Kupfer, 1988). There is evidence from several clinical studies that antidepressant use in general is associated with weight gain, although some differences are reported by the type of antidepressants (Masand and Gupta, 2002; Serretti and Mandelli, 2010). In contrast, the effect of depression on body weight can be theoretically ambiguous. On the one hand, depression may increase the likelihood of obesity by reducing activity levels and healthful diets and by interfering with stress mechanisms as suggested in some studies (Bornstein et al., 2006; Luppino et al, 2010). On the other hand, depression may also reduce food (or caloric) consumption significantly, which can reduce body weight. Therefore, it is impossible to a priori sign the effect of depression on body weight, which emphasizes the need for empirical investigation.

Figure 1 shows the U.S. adult rates of overweight and obesity, treated depression, and antidepressant use among treated cases of depression between 1987 and 2008. The seemingly related trends between obesity, treated depression, and antidepressant use in the past two decades are consistent with a hypothesis that increasing depression and antidepressant use rates have played a role in the prevalence of obesity. However, there are several obstacles to identifying that causal effect. First, it is not sufficient to adjust for differences only in the observables that affect depression, antidepressant use, and weight gain. Unobserved characteristics such as genetic risks, preferences for health and risk-taking, personality traits, human capital, and social factors can affect depression, antidepressant use, and obesity, causing omitted variables bias. Another challenge to the causal inference, especially in cross-sectional studies, is the reverse effect — the effect of body weight or obesity on depression, possibly through self-image, social interactions, health status, or activity limitations (Granberg, 2011; Carr and Jaffe, 2012). Unlike the possible coexistence of upward and downward biases due to omitted variables, the reverse effect highlights the possibility of over-estimating the effect of depression on body weight or obesity.

Clinical studies of the effect of antidepressant use on weight gain randomly assign patients

diagnosed with depression into a treatment group consisting of those taking antidepressants and a control group including those taking placebos to control for confounders. The estimates vary across studies and by antidepressant type. In a meta-analysis of clinical studies, Serretti and Mandelli (2010) find that two antidepressants — Amitriptyline and Paroxetine — significantly increase body weight at or after four months of treatment, and that a third antidepressant — Mirtazapine — has a positive and marginally significant effect on weight gain. The average effects of these three antidepressants range from an increase of about 2.24–2.73 kilograms (about a 5–6 pound increase). One limitation of the clinical studies is that the enhanced internal validity is achieved at the cost of reduced external validity because samples used for clinical studies are unlikely to be nationally representative due to experiment participation bias, and results from clinical studies may be highly specific to the studies' own environments and may not well reflect the effects for the general population.

In this study we first examine the effects of diagnosed depression with antidepressant use on changes in BMI and body weight status including overweight and obesity, using a longitudinal and nationally representative sample of young adults 18–33 years of age. The longitudinal design allows us to use variation within each individual over time to estimate a composite effect of diagnosed depression and antidepressant use on body weight changes, free of the effects of individual-level time-invariant unobservables which could include preferences for health, seeking medical treatments, and genetic factors.

In an additional analysis, we attempt to separate the effect of antidepressant use from that of depression by controlling for whether individuals exhibit depression symptoms. We find that the previously estimated joint effect remains very similar, which suggests that weight gain is largely explained by the antidepressant use rather than depression symptoms of those who were diagnosed with depression. We provide detailed discussions later.

Identifying the joint effect of diagnosed depression and antidepressant use is important for explaining the rising obesity rates because of the increasing prevalence of both depression and antidepressant use in the population (shown in Figure 1), and because the increase in antidepressant use is in part due to the rising depression rates. To our knowledge, we provide the first nationally representative estimates of the joint effect of diagnosed depression and antidepressant use on body weight for the young adult population in the United States. We find that depression and antidepressant use jointly increase body weight, controlling for individual-level time-invariant unobserved heterogeneities. Overall, the increase in the cases of depression treated with antidepressants at the population-level explains only a small portion of the obesity rise — 1.5 percent. However, the relatively low proportion of the population treated with antidepressants indicates that continuing increases in depression and antidepressant use may significantly elevate obesity rates in the future. Thus, our results have important implications for public health policies.

The rest of this paper is organized as follows. Section 2 describes the data. Section 3 presents our econometric models. Section 4 discusses empirical findings, and Section 5 concludes.

2. Data

We use data from the National Longitudinal Study of Adolescent Health (Add Health). For

several key variables of our study, Add Health provides information about their changes over time for each respondent. Thus, the longitudinal design of Add Health allows us to control for time-invariant heterogeneities that are unobservable at the individual level. Currently, there are four waves of Add Health, which have been tracking a sample of individuals in the United States who were adolescents when first recruited in 1994–95.[1] To make the sample nationally representative, Add Health provides probability weights (that is, sampling weights) for each respondent separately for cross-sectional and longitudinal analyses. The first wave (Wave I) of Add Health randomly selected a group of students in grades 7 to 12 nationwide between September 1994 and December 1995. This cohort was then followed in the next three waves of Add Health, which were conducted between April 1996 and August 1996 (Wave II), between July 2001 and April 2002 (Wave III), and from April–June 2007 (the pretest of Wave IV) to January 2008–February 2009 (the main study of Wave IV). Our study uses the data collected from the two most recent in-home interviews — Waves III and IV — which are available for 15,197 (18–27 years old) and 15,701 respondents (24–33 years old), respectively. For several robustness checks, we also use data from Wave II, which are available for 14,738 individuals (12–22 years old).

In addition to the common information collected in the first three waves, Wave IV of Add Health collected information from each respondent about his or her use of prescription medications during the past four weeks before the in-home interview visit. All the medications are therapeutically classified.[2] There are two questions listed in the survey. The response to the first question determines whether the second question is answered or not. The first question is: "Have you taken any prescription medications in *the last four weeks*?" Among all respondents (15,701) in Wave IV 5,820 answered "yes" (37.07%); 9,876 answered "no" (62.90%); four respondents answered "don't know" (0.02%); and one refused to answer the question (0.01%). There are 10,711 total medications reported by those who answered "yes" to the first question (5,820 respondents in total). Thus, each of those medication users has an average of 1.84 medications (with the range from 1 to 18 medications). Among the reported medications 8,366 (78.11%) were checked and recorded by the interviewers during the in-person interviews: interviewees were asked to assemble the medications or their containers prior to the interviews and to present them to the interviewers. The rest of the reported medications (2,345 or 21.89%) were based on the respondents' memory, in which case the interviewers were unable to verify the medication information.

The second question listed in the medication survey is answered only by those who answered "yes" to the first question (5,820 respondents in total). The second question is: "Did you take any additional medications?" There are 2,533 respondents (43.52% of the 5,820 medication users) who answered "yes" to the second question and also gave their full lists of medication uses, which were checked and recorded by the interviewers.

All medications are therapeutically classified by nine-digit codes based on the Multum Lexicon™.[3] We first screen out the medications that have psychotherapeutic agents by the codes starting with "242-xxx-xxx," where "x" indicates an integer between 0 and 9. This selection includes 1,145 medications that were taken by 981 respondents in the estimation sample. Out of those 1,145 medications, 977 (or 85.33%) medications are antidepressants (identified by the code "242-249-xxx"), and the rest 168 medications (or 14.67%) are antipsychotics (identified by the code "242-251-xxx"). Among the 981 respondents, 832 (or 84.81%) used antidepressant

medications only; 77 (or 7.85%) used antipsychotics only; and 72 (or 7.34%) used both. To focus on the effect of antidepressant medications, we drop from our estimation sample those 149 users who used either antipsychotics only, or both antipsychotics and antidepressants. In Appendix Table A1 we explain in detail how we construct the sample for our analyses.

To isolate the joint effect of diagnosed depression and antidepressant use on body weight from the effects of individual-level time-invariant unobservables, ideally we would utilize the changes over time in each respondent's depression diagnosis and antidepressant use. However, we are unable to do so because information about prescription medications like the one in Wave IV was not collected in the previous three waves. Nevertheless, respondents were asked at Wave III about whether they had ever been diagnosed with depression as of the dates when they received the in-home interviews. This information allows us to identify individuals who had never been diagnosed with depression and therefore would not have used antidepressant medications by Wave III — our estimation sample is limited to these individuals. In other words, we exclude from our estimation sample those who had been diagnosed with depression by Wave III since we cannot measure their use of antidepressants at that time. This implies that our sample excludes those who had been diagnosed with depression before age 18 years (the minimum observed age in Wave III). Since those who experience depression before age 18 years may be different from those experiencing depression at older ages, our results may not be generalizable to the earlier group and can only be generalized to those who experience depression after age 18 years. Nonetheless, this exclusion is necessary for us to correctly measure the change in antidepressant use between Waves III and IV. Furthermore, we also drop from our estimation sample those who had no diagnosis information about depression in Wave III.[4] In sum, our analysis is conditional on those who had never been diagnosed with depression by the end of Wave III, and for this population it is reasonable to assume that no one used antidepressants in Wave III. Making this assumption is necessary for our analysis in order to be able to measure the changes in the use of antidepressants over time, because there is no information about antidepressant medications at Wave III like the information collected in Wave IV. However, since it is possible that some individuals who reported not having been diagnosed with depression at Wave III may have been using antidepressants at that time, our estimates may be considered a lower-bound of the effect for our study population.

We use BMI to measure body weight.[5] Except for the first wave of Add Health, each respondent's height and weight were measured by the interviewer at the time of the in-home (and also in-person) interview. Based on BMI we next measure body weight status by an indicator equal to one for being either overweight or obese, and zero otherwise. For individuals under 21 years of age we use the CDC definition of overweight and obesity: overweight is defined as BMI greater than or equal to the 85th percentile and less than the 95th percentile of the BMI distribution; obesity is defined as BMI greater than or equal to the 95th BMI percentile. Those percentiles are specific to age and gender and are defined for each age-gender group, because adolescents' body weight can change significantly during their growth spurts, and the change differs by gender. In Appendix Table A2 we list the 5th, the 85th, and the 95th percentiles of the BMI distribution for individuals younger than 21, and for both males and females.[6] For individuals 21 years of age or above, obesity is defined by BMI greater than or equal to 30 and overweight is defined by BMI greater than or equal to 25 and less than 30.

3. Econometric Models

To examine the joint effect of diagnosed depression and antidepressant use on body weight, we start with the following regression model using panel data from Waves III and IV:

$$y_{it} = \alpha_i + \beta_1 d_{it} + \boldsymbol{\beta}_2' \mathbf{x}_{it} + \beta_3 T_t + \boldsymbol{\beta}_4' \mathbf{w}_i T_t + u_{it} \ (i = 1, 2, \cdots, N; t = 1, 2) \quad (1)$$

where u_{it} is the mean zero disturbance term. In this model we consider two cases for y_{it}: the first one is the BMI of individual *i* at time *t* (*t* equal to 1 for Wave III and 2 for Wave IV); the second case is the associated body weight status — an indicator for being overweight or obese. In the following analyses we label this indicator as "overweight/obesity." The model described in equation (1) acknowledges the presence of individual-level time-invariant unobservables represented by α_i. To examine the joint effect of diagnosed depression and antidepressant medications we use a binary dummy variable *d*, which represents taking antidepressant medications in the past four weeks for those who were diagnosed with depression. The comparison group — relative to the treatment group composed of those who were diagnosed with depression and who took antidepressant medications — consists of those who were never diagnosed with depression and had no antidepressant medications at Wave IV. As previously mentioned, it is possible that some individuals in the comparison group may have taken antidepressants at Wave III but reported no depression diagnosis.[7] However, this is expected to be a small proportion, which will result in our estimates being considered a lower bound of the effect of depression and antidepressant use.

In all our regression analyses we exclude from our estimation sample those who were ever diagnosed with depression and reported no antidepressant medications during the four-week period prior to the dates of their Wave IV in-home interviews. The reason is that to isolate the effect of antidepressant use from the effect joint with depression, we would consider a comparison group consisting of those who were diagnosed with depression at Wave IV but were not taking antidepressant medications; however, using the Add Health data we are unable to construct this comparison group to disentangle the effect of antidepressant medications from the effect of depression. The data limitation comes from the fact that the depression diagnosis information collected by Add Health is only about whether or not an individual has *ever* been diagnosed with depression by the time of the interview. Thus, it is impossible to separate the case of someone who was diagnosed with depression and was treated with antidepressants and also was cured before Wave IV from the case of someone who was diagnosed with depression shortly before Wave IV and was not treated with antidepressants. Because we do not have the information about whether and when depression was cured for those who were ever diagnosed with depression and also had not used antidepressants one month prior to the dates of their Wave IV in-home interviews, we are unable to identify those who were still in a depression episode from those who were ever diagnosed with depression and also were not taking antidepressant medications at Wave IV. As a result, we are unable to compare those who were diagnosed with depression and were not taking antidepressant medications with those who were taking antidepressant medications at Wave IV, in order to identify the effect solely attributable to antidepressant medications. Nonetheless, in an additional specification we are able to control for depression symptoms, to check if the previously estimated joint effect remains similar. If so, this would suggest that weight gain is mainly driven by the antidepressant use of those who were diagnosed with depression as opposed to their depression symptoms. We will give further discussions on this additional estimation later.

Other control variables in equation (1) are the following: 1) $\mathbf{x}_{it}$, a vector of time-varying characteristics of individual *i* (including age, whether having college education, personal earnings, being married or not, and frequencies of smoking and drinking during the past month); being pregnant or not is controlled for in the regression analysis specific for females; 2) T_t, a binary dummy variable indicating whether an individual was interviewed at Wave III (equal to 0) or Wave IV (equal to 1); and 3) $\mathbf{w}_i T_t$, the interaction between T_t and $\mathbf{w}_i$ — a vector of time-invariant characteristics of individual *i* (including gender, race and ethnicity, birth weight, whether breastfed or not, parental education, and parental obesity status).

As mentioned above, we use *t* in equation (1) to denote the wave of Add Health in-home interviews. To simplify notation we do not further denote different timings within each wave. We herein clarify that the height and weight of a respondent were measured on the date of his or her interview, but the activities of the respondent being measured in d_{it} and $\mathbf{x}_{it}$ occurred prior to his or her interview date. Thus, d_{it} and $\mathbf{x}_{it}$ are predetermined variables relative to the BMI or the body weight status variable y_{it} used as the dependent variable in equation (1). In Appendix Table A3 we give detailed descriptions and definitions of all the variables included in the regression model.

Based on equation (1), we next obtain a first-differenced version as follows:

$$\Delta y_i = \gamma_0 + \Delta d_i \gamma_1 + \Delta \mathbf{x}_i' \boldsymbol{\gamma}_2 + \mathbf{w}_i' \boldsymbol{\gamma}_3 + \varepsilon_i \ (i = 1, 2, \cdots, N) \tag{2}$$

where ε_i is the mean zero disturbance term. In this first-difference model we also exclude from our estimation sample those who have ever been diagnosed with depression but without antidepressant medications at Wave IV for exactly the same reason given above for the regression model described in equation (1). In our estimation sample from Wave III, we exclude those who had ever been diagnosed with depression by Wave III or who had no diagnosis information about depression at Wave III; this sample selection procedure is explained in the data section above and in Appendix Table A1 in detail. As a result, none of the individuals in our estimation sample had been diagnosed with depression at Wave III, and therefore we can assume that they did not have antidepressant medications at that time, which makes Δd equivalent to *d* measured at Wave IV.

In equation (2) we also include the BMI measured at the previous wave into $\mathbf{w}_i$ for two reasons: the first one is to account for any possible mean reversion in BMI, which is indicated by a negative relationship between a change in BMI between the two waves and the BMI at the initial wave (Chay et al., 2005); and the second reason is to allow for the possibility that depression and antidepressant use at Wave IV are dependent on BMI in Wave III. In other words, this allows us to account for the possible effect of BMI on depression and antidepressant use.

We use equation (2) as our preferred specification in the following regression analyses. To estimate population-level parameters (that is, census parameters), we apply the weighted least squares (WLS) estimator to equation (2), using the longitudinal probability weights provided by

Add Health — these probability weights are constructed by Add Health specifically for longitudinal analyses based on Waves III and IV. To assess the direction of bias (e.g., biased upward or downward) resulting from ignoring individual-level time-invariant unobservables, we estimate equation (1) by WLS without controlling for individual-level fixed effects and then compare the estimates with those obtained by WLS based on equation (2), in which case individual-level fixed effects are differenced out.

4. Empirical Results

Table 1 reports the summary statistics, separately for Waves III and IV, based on the estimation sample used for estimating equation (2). In computing those statistics we apply the longitudinal probability weights to obtain estimates that are nationally representative. Constructions of samples based on Wave III and IV for regression analyses are explained in Appendix Table A1. Descriptions and definitions of the variables are given by Appendix Table A3.

4.1. Joint Effects of Diagnosed Depression and Antidepressant Use on Body Weight without Controlling for Individual Fixed Effects

Table 2 reports the WLS estimates based on equation (1) without controlling for individual fixed effects. Note that there are twice as many observations used in this estimation as the ones used in estimating equation (2), because each individual is included twice, in Waves III and IV. In Table 2 we find that the joint effect of depression and antidepressant use on BMI is significant (shown in column 1) — on average increasing BMI by approximately 2.4 points. Similarly, the joint effect of diagnosed depression and antidepressant use on the probability of becoming overweight or obese is approximately a 15-percentage point increase (shown in column 3).

As previously discussed, the WLS estimates based on equation (1) are likely biased because of omitted individual-level heterogeneities such as genetic factors. One way to detect this bias is to examine the association between depression and antidepressant use at Wave IV and body weight at Wave III. This association may exist although there cannot be any causal effect of later depression and antidepressant use on earlier body weight changes. The existence of such an association would indicate that certain time-invariant unobserved factors affect both depression and antidepressant use and body weight, or that there are effects of body weight on future depression and antidepressant use. To implement this check, we regress body weight (or body weight status) measured in Wave III on antidepressant use measured in Wave IV. Columns (2) and (4) of Table 2 report the results of this check. We find that future depression and antidepressant use are jointly associated with past weight gain, which indicates that the estimates reported in columns (1) and (3) of Table 2 are likely to be inconsistent in the presence of individual-level time-invariant unobservables and the effects of body weight on depression and antidepressant use.

4.2. Joint Effects of Diagnosed Depression and Antidepressant Use on Body Weight Controlling for Individual Fixed Effects

We report the estimates of the joint effects of diagnosed depression and antidepressant use on BMI and overweight/obesity based on the first-difference model described in equation (2) in columns (1) and (3) of Table 3, respectively. Note that this model controls for body weight at

Wave III. The joint effect — approximately 1 BMI unit or 7 pounds assuming a height of six feet[8] — is less than half of the one (2.412 BMI units) shown in column (1) of Table 2. This suggests that individual-level time-invariant unobserved heterogeneities could be correlated in the same direction with both body weight and depression and antidepressant use. We also observe this correlation pattern in the case of overweight/obesity, in which we find that depression and antidepressant use could increase the probability of becoming overweight/obese by about 9.2 percentage points based on the first-difference model, which is slightly over half of the effect without controlling for individual-level fixed effects (0.150, shown in column 3 of Table 2).

To assess the validity of the regression model described in equation (2) we conduct two falsification checks and present the results in columns (2) and (4) of Table 3. For the first check we replace the changes in BMI between Waves III and IV with the changes between Waves II and III, and control for BMI at Wave II instead of Wave III; the results are shown in column (2). For the second check we repeat the same replacement for the changes in overweight/obesity status; the results are shown in column (4). The goal of both falsification checks is to see whether there exist any unobserved and possibly time-varying factors that affect both body weight and depression and antidepressant use. If those factors are omitted from our regression model described in equation (2), then we could find a correlation between current depression and antidepressant use and past weight gain or past changes in body weight status. However, in Table 3 we do not find empirical evidence supporting that correlation. In column (2) we find no significant joint effect of depression and antidepressant use in Wave IV on weight gain between Waves II and III. Similarly, in column (4) we find no significant joint effect of depression and antidepressant use in Wave IV on the changes in overweight/obesity status between Waves II and III. These falsification checks suggest that the specification of our regression model described in equation (2) is valid.

To further check the robustness of results in Table 3, we add two time-varying binary (1/0) variables to the regression model described in equation (2). One variable is "having health insurance (1) or not (0) at the time of the interview," and the other variable is "currently working for pay for at least 10 hours a week (1) or not (0)." We include these two variables as proxies to control for additional time-variant shocks that affect both the occurrence of depression and weight gain. Here, we repeat the estimations shown in Table 3 and report the new estimates in Appendix Table A4. We find that the estimates of the joint effects of diagnosed depression and antidepressant use on BMI and overweight/obesity shown in columns (1) and (3) of Appendix Table A4 are very similar to the ones shown in columns (1) and (3) of Table 3.

4.3. Heterogeneities in the Joint Effects of Diagnosed Depression and Antidepressant Use on Body Weight

Given that antidepressant use and depression influence body weight through biological, behavioral, and psychosocial pathways, it is possible that the effects may vary by demographic, economic, and health characteristics. Identifying this heterogeneity is important for understanding the pathways through which depression and antidepressant use affect body weight. Moreover, identifying the most affected groups is important for developing targeted and effective interventions to reduce weight gain resulting from depression and antidepressants. Therefore, we examine the joint effect of depression and antidepressant use by gender, initial

body weight (measured in Wave III), income, and marital status. We do this by estimating equation (2) stratified by these variables, and report the results in Table 4. We do not stratify by race due to the small sample size for minority groups.

Panel A in Table 4 reports the joint effect of depression and antidepressant use from equation (2) separately for males and females. The effect is slightly larger for females than for males, but none of the effects is statistically significant, likely due to the reduced sample size. Panel B reports the joint effects of depression and antidepressant use separately for individuals who were overweight/obese at Wave III and for those who were not. The joint effects on both BMI and overweight/obesity are twice as large for those who were initially not overweight/obese (at Wave III) as those who were, increasing their BMI by approximately 1.24 points. However, the joint effect on overweight/obesity is statistically insignificant for this group. The joint effect on BMI for individuals who were overweight/obese at wave III is also insignificant.

Next, we stratify the regression analyses based on equation (2) by the median of personal earnings (shown in Panel C). The median of personal earnings in Wave IV is $30,000 (based on 15,127 observations in the full sample). We find that the effect of depression and antidepressant use on BMI is statistically insignificant but overall comparable between those below and those above the median. In contrast, the effect on overweight/obesity is twice as large among the group with personal earnings below the median, for whom the probability of becoming overweight or obese increases by 12.1 percentage points (which is marginally significant). The effect of depression and antidepressant use on overweight/obesity for the higher income group is statistically insignificant.

Finally, we stratify the regression analyses based on equation (2) by marital status categories in Waves III and IV. In order to maintain a reasonable sample size for each stratum, we only estimate the joint effect of depression and antidepressant use separately for the two most common groups — including those who were not married in either Waves III or IV and those who were not married in Wave III but were married in Wave IV. We find that the effect of depression and antidepressant use on BMI and overweight/obesity is larger for those who were unmarried in both Waves, increasing their BMI by about 1 point (which is marginally significant) and their probability of becoming overweight/obese by 15.1 percentage points. In contrast, the effects on BMI and overweight/obesity for those who were not married in Wave III but married in Wave IV are insignificant.

4.4. Potential Channels for the Joint Effects of Diagnosed Depression and Antidepressant Use on Body Weight

The literature highlights three main pathways through which depression and antidepressant medications are likely to affect body weight — food consumption, physical activity, and metabolic rate. The two most apparent pathways are through modifying dietary habits and activity level. Depression may reduce healthful food consumption and physical activity level and exercise. Antidepressants may increase appetite and, as a result, food consumption. They may also affect activity level. Other suggested and less understood pathways include effects of antidepressants on reducing metabolic rate.

Add Health has limited data on food consumption and physical activity and no data on

metabolism. Specifically, there are two questions on the number of days/times of eating at fast food restaurants in the past seven days, and whether there was any physical exercise also in the past seven days. These two measures are clearly limited in their ability to fully account for all the effects of depression and antidepressant use through diet and physical activity. The fast food consumption measure does not reflect the amount of fast food consumed and caloric intake. Also, food consumption at home or at regular food restaurants is not observed. Similarly, the physical exercise measure does not reflect the rigor or the intensity of exercise. Nonetheless, these two indicators are useful in providing some information about the pathways of food consumption and physical activity between depression and antidepressant use and body weight. In Table 5 we report the results on the evaluation of the influences of diet and physical activity by adding the two dietary and exercise measures described above to the regression model (equation 2). We find that the effect of depression and antidepressant use is slightly smaller when including those two variables, as shown in Table 5 compared with columns (1) and (3) of Table 3. Despite the limitations of those two measures, we find suggestive evidence that part of the joint effect of depression and antidepressant use on body weight occurs through fast food consumption and exercise. However, the results highlight the need for better measures of diet and physical activity to adequately examine the extent to which they mediate the observed effect of depression and antidepressant use on body weight.

4.5. Controlling for Depression Symptoms

In order to differentiate between the effect of diagnosed depression and antidepressant use and that of depression symptoms, we control for the individual's change in depression symptoms between Waves III and IV. Depression symptoms are measured by the Center for Epidemiological Studies–Depression (CES-D) scale (Radloff, 1977), a commonly used measure that correlates well with other measures of depression symptomatology. It is typically constructed based on 20 questions with responses using a 4-point scale (from 0 to 3). However, only nine out of the 20 questions were asked in both Wave III and Wave IV of Add Health interviews. Thus, the range of the CES-D scale based on the nine questions is between 0 and 27 with reverse coding needed for positively worded questions.

We re-estimate the regression model described by equation (2), separately for BMI and overweight/obesity in two cases. In the first case we control for the change in the total score of the CES-D, which captures the change in the level of depression. In the second case we focus on relatively severe depression by controlling for the change in having major depressive disorder symptoms or not. To create a binary indicator (1/0) for having major depressive disorder symptoms (1) or not (0), we follow the method proposed by Spriggs and Halpern (2008). For the same nine questions in Add Health, they use the cutoff points of 10 for males and 11 for females. Both cutoff points are proportionally adjusted based on the cutoffs of 22 and 24, for males and females respectively, with the full set of 20 questions.

The results for these two additional specifications are shown in columns (2) and (6), and (3) and (7) of Table 6 for the total depression score and the major depression indicator, respectively. For comparison purposes, columns (1) and (5) repeat columns (1) and (3) of Table 3. In both cases of including the changes in depression symptoms between Wave III and Wave IV, we find that our previously estimated joint effects shown in columns (1) and (5) remain very similar. This suggests that weight gain is largely explained by the use of antidepressants instead of depression

symptoms. Depression symptoms measured by the total CES-D score or its derived binary indicator for major depressive disorder symptoms have negative effects on BMI and overweight/obese status; only the latter effects are statistically significant.

In another way to control for depression symptoms, we drop from our estimation sample those who did not take antidepressants and did not exhibit major depressive disorder symptoms — that is, we keep in our estimation sample those who either had antidepressant medications, or had major depressive disorder symptoms, or had both. Despite the greatly reduced sample size, our estimated depression and antidepressant effects shown in columns (4) and (8) of Table 6 still remain positive and statistically significant with larger magnitude. Overall, results in Table 6 suggest that the effect of antidepressant use is the main contributor to the joint effect.

5. Conclusions

Using a nationally representative sample of young adults in the United States and controlling for unobserved individual-level time-invariant heterogeneity, we find that diagnosed depression and antidepressant use could significantly increase BMI and the likelihood of becoming overweight or obese. To the best of our knowledge, we provide the first empirical evidence of the joint effect of diagnosed depression and antidepressant use on body weight based on a nationally representative sample of young adults in the United States.

Among adults under 65 years of age, young adults have had the largest rates of weight increase. Between 1971 and 2006, the rates of overweight/obesity increased by 44 percent and 97 percent among males and females 20–34 years of age, respectively, compared to 22 percent and 50 percent among males and females aged 35–44 years (Ogden and Carroll, 2010). At the same time, the rate of young adults diagnosed with depression and treated with antidepressants increased by 400 percent from 1987 to 1998, and by 8 percent from 1998 to 2007 (Olfson et al, 2002; Marcus and Olfson, 2010). Table 7 reports our calculation of the population-level increase in overweight/obesity among young adults that might be explained by the population-level increase in depression cases treated with antidepressants. Our empirical findings suggest that among young adults the increase in depression cases treated with antidepressants might explain approximately 1 percent of the increase in overweight/obesity rate from 1988–1994 to 1999–2000, and about 0.5 percent of the increase in the overweight/obesity rate from 1999–2000 to 2007–2008.

The finding that antidepressant use could explain only a small percentage of the population-level overweight/obesity rise over the past two decades is not surprising given the relatively small percentage of the population treated with antidepressants (less than 2 percent). However, the CDC has recently updated the estimate of depression prevalence among adults, which is 9.1 percent (CDC, 2011b). If all individuals diagnosed with depression were to be treated with antidepressants, our results would suggest that population overweight/obesity rates would increase by another 1 percentage point, which would be about one third of the entire overweight/obesity increase over the last decade. Larger overweight/obesity rate increases would occur among the lower income and unmarried individuals, who are also estimated to have larger depression rates. The CDC estimates that 11.8 percent of never-married individuals and 11.3–17.1 percent of individuals with high school or less education may have depression. In our study we find larger joint effects of depression and antidepressant use for unmarried and low

income individuals. Our results suggest that overweight/obesity rates among unmarried individuals would increase by 1.5 percentage points if antidepressants were provided for all cases.

Our empirical findings have several public health and policy implications. First, they highlight some, although overall modest, contribution of increasing depression cases treated with antidepressants to the population rise in the rates of overweight and obesity. Halting the rise in obesity rate and reducing the rates of overweight and obesity are major public health and policy objectives. Previous observational studies have been able to explain only a small percentage of the increase in the obesity rate. However, none of the previous studies using national samples accounted for the role of depression and antidepressants in the increasing obesity rate. Our study suggests an additional pathway for obesity prevention and reducing the high obesity rate — reducing depression and antidepressant use. Of course, this is an extremely challenging objective given the complexity of depression and the adverse consequences of reducing antidepressant use in terms of increased rates of untreated depressions and substitution to other therapies that may also have unintended adverse consequences. However, one approach to reducing the risk of weight gain may be through healthcare providers informing patients prior to treatment about the risks and identifying interventions to prevent weight gain such as through enrollment in dietary and physical activity programs and monitoring weight gain. While antidepressant use is in part a function of depression occurrence, our results suggest that the effect on weight gain is mostly due to antidepressants, not depression. Therefore, policy efforts aimed at reducing body weight should focus on the use of antidepressants as one pathway contributing to the obesity rise.

Our study has four main limitations that require to be addressed in future studies with additional data. First, we cannot completely disentangle the effect of antidepressants from that of depression due to the limitation of the Add Health data. Nonetheless, we are able to estimate the joint effect of depression and antidepressant use. This effect is of major interest from a public health and policy perspective in order to understand the effect of the population rise in depression and antidepressant treatments on obesity trends over the past four decades. However, isolating the antidepressant effect is also of interest in order to identify the source of the effect and develop interventions and policies. Although we cannot completely achieve that, we are able to differentiate out the effect of depression symptoms. By doing so, we find evidence that the increase in weight gain is likely due to antidepressants, not depression. Second, we cannot evaluate the effects of specific antidepressants but an average effect across all antidepressants. Since clinical studies have found differences in the effects of various antidepressants on body weight, it is likely that our results are overestimating the effects for some antidepressants and underestimating the effects for others. Therefore, evaluating the effects of specific antidepressants in nationally representative data samples is needed. Third, our results are only generalizable to individuals who had not been diagnosed with depression before 18 years of age. As this group may be different from those who experience earlier onset of depression in factors that could modify the relationship between depression/antidepressants and body weight, specific studies that can evaluate the effects of antidepressants and depression among children and adolescents are needed. Finally, we are unable to adequately explore the pathways through which depression and antidepressant use result in weight gain, due to the lack of detailed data on food consumption, activity level, and metabolic rate. We leave this question to future studies.

Endnotes

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1. Detail is provided at http://www.cpc.unc.edu/projects/addhealth/design.

2. More detail is provided at http://www.cpc.unc.edu/projects/addhealth/data/guides.

3. The Multum Lexicon^{TM} uses a three-level therapeutic classification scheme: 1) 19 first-level codes; 2) more than 150 second-level codes; and 3) more than 175 third-level codes. Note that the classification is not a hierarchical numbering system.

4. In Appendix Table A1 we give detailed explanation about this sample selection process and the corresponding changes in the sample size.

5. BMI = weight (in kilograms) / height (in meters) squared = 703 × weight (in pounds) / height (in inches) squared. Although BMI does not directly measure body fat, it is widely used as a body weight measure and proxy for total body fat.

6. The CDC's classification of body weight status (a binary variable) is the following: 1) obesity equals 1 if BMI ≥ the 95th percentile, and 0 otherwise; 2) overweight equals 1 if the 85th percentile ≤ BMI < the 95th percentile, and 0 otherwise; 3) normal weight equals 1 if the 5th percentile ≤ BMI < the 85th percentile, and 0 otherwise; and 4) underweight equals 1 if BMI < the 5th percentile, and 0 otherwise. We use these cutoffs for our study population to classify their body weight status. For those who are at least 21 years old, the CDC's classification of body weight status (a binary variable) based on BMI is deterministic and regardless of gender: 1) obesity equals 1 if BMI ≥ 30 and 0 otherwise; 2) overweight equals 1 if 25 ≤ BMI < 30, and 0 otherwise; 3) normal weight equals 1 if 18.5 ≤ BMI < 25, and 0 otherwise; and 4) underweight equals 1 if BMI < 18.5, and 0 otherwise. In our study, we use these fixed cutoffs (18.5, 25 and

30) for respondents who are at least 21 years old.

7. We drop from our estimation sample 313 observations (out of 30,898 observations from 17,864 respondents in the combined Wave III and IV sample) of those who had used antidepressants but reported that they had never been diagnosed with depression. For additional detail, see Appendix Table A1.

8. $(6\times12)^2 \times 1/703 \approx 7.374$.

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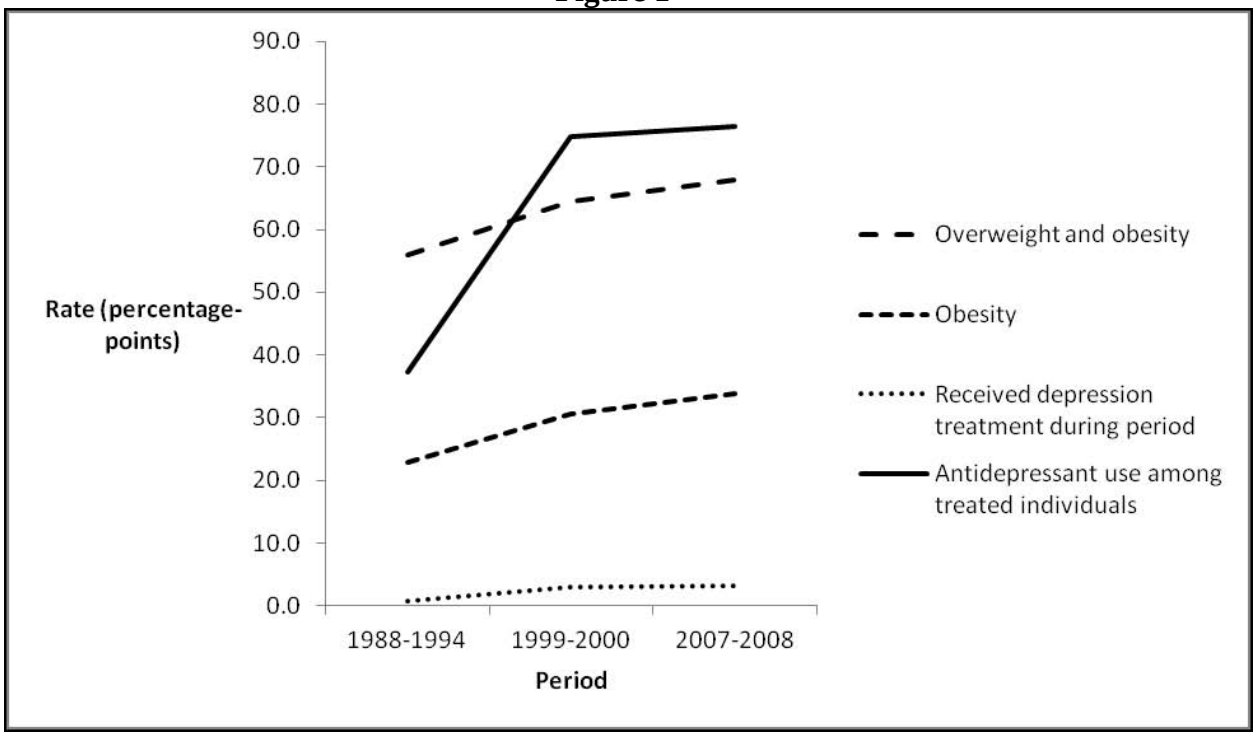
Figure 1



Notes: Overweight and obesity data are from Ogden et al. (2010). Depression and antidepressant use data are from Olfson et al. (2002) and Marcus et al. (2007). In the figure, depression refers to diagnosed depression.

Table 1. Summary Statistics

	Wave III			Wave IV		
Variables	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
BMI	3,753	26.040	5.805	3,753	28.590	7.248
Obese	3,753	0.196	0.397	3,753	0.338	0.473
Overweight	3,753	0.244	0.430	3,753	0.304	0.460
Normal weight	3,753	0.532	0.499	3,753	0.346	0.476
Underweight	3,753	0.028	0.164	3,753	0.012	0.110
Diagnosed with depression	3,753	0.000	0.000	3,753	0.030	0.170
Antidepressant medication	3,753	0.000	0.000	3,753	0.030	0.170
Diagnosed with depression and taking antidepressant medications	3,753	0.000	0.000	3,753	0.030	0.170
Diagnosed with depression but without antidepressant medications	3,753	0.000	0.000	3,753	0.000	0.000
CES-D (based on 9 items)	3,742	3.763	3.460	3,751	4.330	3.476
Having major depressive disorder symptoms	3,742	0.061	0.240	3,751	0.067	0.250
Having health insurance or not at the time of the interview	3,723	0.782	0.413	3,733	0.806	0.396
Age	3,753	21.255	1.602	3,753	27.750	1.613
College	3,753	0.602	0.490	3,753	0.709	0.454
Personal earnings	3,753	11.715	14.137	3,753	37.126	41.275
Currently working for pay	3,753	0.759	0.428	3,752	0.688	0.463
Married	3,753	0.106	0.308	3,753	0.389	0.488
Pregnant	3,753	0.019	0.137	3,753	0.032	0.177
Smoking	3,753	8.838	13.121	3,753	8.296	12.710
Drinking	3,753	4.695	6.432	3,753	5.396	6.862
Exercise	3,753	0.848	0.359	3,753	0.885	0.319
Fast food	3,753	2.451	2.044	3,747	2.201	2.726
Male	3,753	0.566	0.496	3,753	0.566	0.496
White	3,753	0.855	0.352	3,753	0.855	0.352
Black	3,753	0.110	0.312	3,753	0.110	0.312
Hispanic	3,753	0.108	0.310	3,753	0.108	0.310
Asian	3,753	0.036	0.186	3,753	0.036	0.186
Birth weight	3,753	7.510	1.204	3,753	7.510	1.204
Not breastfed	3,753	0.499	0.500	3,753	0.499	0.500
College education of either parents	3,753	0.355	0.478	3,753	0.355	0.478
Biological mother being obese	3,753	0.181	0.385	3,753	0.181	0.385
Biological father being obese	3,753	0.112	0.315	3,753	0.112	0.315

Note: Variables are obtained from Waves III and IV questionnaires of Add Health. Questionnaires are available at the following website: http://www.cpc.unc.edu/projects/addhealth/codebooks. Constructions of samples based on Wave III and IV for regression analyses are explained in Appendix Table A1. Descriptions and definitions of the variables are given by Appendix Table A3. The summary statistics are based on the estimation sample, which is the one used for estimating equation (2) which is explained in the main text. Longitudinal probability weights provided by Add Health are used.

Table 2. Joint Effects of Depression and Antidepressant Use on Body Weight without Controlling for Individual Fixed Effects

Dependent variable:	BMI		Overweight/Obesity	
	Main result	Falsification check	Main result	Falsification check
	(1)	(2)	(3)	(4)
Diagnosed with depression and taking antidepressant medications	2.412***	1.470**	0.150***	0.094*
	(0.862)	(0.738)	(0.050)	(0.053)
Age	0.138**	0.211***	0.024***	0.043***
	(0.059)	(0.074)	(0.005)	(0.006)
College	-0.514**	-0.328	-0.040**	-0.032
	(0.230)	(0.295)	(0.016)	(0.025)
Personal earnings	-0.003*	0.000	0.000	0.000
	(0.002)	(0.002)	(0.000)	(0.000)
Married	0.531**	-0.254	0.051***	0.002
	(0.251)	(0.255)	(0.018)	(0.022)
Smoking	-0.014*	-0.009	-0.001**	-0.001
	(0.008)	(0.010)	(0.001)	(0.001)
Drinking	-0.060***	-0.100***	-0.003***	-0.007***
	(0.014)	(0.016)	(0.001)	(0.001)
Male	0.157	0.228	0.049**	0.052**
	(0.241)	(0.248)	(0.021)	(0.021)
White	-0.789	-0.827	-0.075*	-0.078*
	(0.562)	(0.566)	(0.042)	(0.043)
Black	0.373	0.385	-0.003	-0.002
	(0.620)	(0.618)	(0.048)	(0.049)
Hispanic	0.614	0.641*	0.052	0.054
	(0.393)	(0.388)	(0.034)	(0.034)
Birth weight	0.288***	0.279***	0.028***	0.026***
	(0.098)	(0.097)	(0.008)	(0.008)
Not breastfed	0.479*	0.458*	0.066***	0.059***
	(0.246)	(0.245)	(0.021)	(0.022)
College education of either parents	-0.768***	-0.726***	-0.037*	-0.031
	(0.239)	(0.241)	(0.022)	(0.022)
Biological mother being obese	2.571***	2.496***	0.160***	0.152***
	(0.366)	(0.360)	(0.029)	(0.029)
Biological father being obese	3.028***	3.017***	0.129***	0.124***
	(0.491)	(0.484)	(0.035)	(0.034)

T (equal to 1/0 for Wave IV/III)	0.426		-0.087	
	(1.470)		(0.111)	
Interactions between *T* and the following variables				
Male	0.501		0.077***	
	(0.386)		(0.028)	
White	0.530		0.102*	
	(0.801)		(0.058)	
Black	1.744*		0.182***	
	(0.904)		(0.065)	
Hispanic	0.371		0.087*	
	(0.592)		(0.044)	
Birth weight	-0.014		-0.003	
	(0.165)		(0.012)	
Not breastfed	0.449		-0.037	
	(0.389)		(0.030)	
College education of either parents	-0.151		-0.002	
	(0.377)		(0.030)	
Biological mother being obese	0.657		0.013	
	(0.576)		(0.037)	
Biological father being obese	0.282		-0.023	
	(0.763)		(0.045)	
Constant	21.354***	18.678***	-0.271**	-0.940***
	(1.576)	(2.270)	(0.122)	(0.191)
Observations	7,506	3,753	7,506	3,753

Note: Data are from the in-home interviews of Waves III and IV of Add Health. Descriptions and definitions of the variables are given by Appendix Table A3. In columns (1) and (3), the dependent variables are measured at Waves IV and III; in columns (2) and (4), the dependent variables are measured at Wave III. "Overweight/Obesity" represents being overweight, obese, or both. Panel robust standard errors (clustered by respondent) are in parentheses in columns (1) and (3). Heteroskedasticity-robust standard errors are in parentheses in columns (2) and (4). Longitudinal probability weights provided by Add Health are used. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3. Joint Effects of Depression and Antidepressant Use on Body Weight with Individual Fixed Effects Controlled for

Dependent variable:	Δ BMI		Δ Overweight/Obesity	
	Main result	Falsification check	Main result	Falsification check
	(1)	(2)	(3)	(4)
Diagnosed with depression and taking antidepressant medications	1.007**	0.270	0.092*	-0.012
	(0.483)	(0.438)	(0.050)	(0.059)
Δ Age	0.196	-0.264**	-0.003	-0.015
	(0.176)	(0.134)	(0.018)	(0.019)
Δ College	0.296	0.413**	0.007	-0.009
	(0.286)	(0.185)	(0.021)	(0.023)
Δ Personal earnings	-0.002	-0.000	-0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
Δ Married	0.650***	-0.326**	0.034*	0.012
	(0.190)	(0.141)	(0.019)	(0.020)
Δ Smoking	-0.027***	0.006	-0.002*	0.000
	(0.009)	(0.007)	(0.001)	(0.001)
Δ Drinking	-0.006	-0.031***	0.001	-0.003*
	(0.014)	(0.009)	(0.001)	(0.001)
Male	0.486**	-0.053	0.079***	0.012
	(0.192)	(0.145)	(0.019)	(0.019)
White	0.533	-0.538*	0.086**	-0.043
	(0.326)	(0.307)	(0.038)	(0.036)
Black	1.714***	-0.264	0.188***	0.026
	(0.376)	(0.344)	(0.044)	(0.043)
Hispanic	0.351	-0.131	0.101***	-0.001
	(0.305)	(0.245)	(0.030)	(0.035)
Birth weight	-0.002	0.053	0.004	0.018**
	(0.092)	(0.062)	(0.008)	(0.009)
Not breastfed	0.457**	0.068	-0.024	0.046**
	(0.187)	(0.147)	(0.020)	(0.021)
College education of either parents	-0.210	-0.200	-0.023	0.016
	(0.185)	(0.151)	(0.020)	(0.021)
Biological mother being obese	0.729***	-0.031	0.068***	0.014
	(0.282)	(0.218)	(0.027)	(0.027)
Biological father being obese	0.330	1.217***	0.045	0.038
	(0.334)	(0.260)	(0.031)	(0.031)

BMI in Wave III	-0.019		-0.022***	
	(0.022)		(0.001)	
BMI in Wave II		-0.017		-0.011***
		(0.021)		(0.001)
Constant	0.307	5.515***	0.594***	0.364**
	(1.288)	(1.090)	(0.144)	(0.142)
Observations	3,753	3,742	3,753	3,742

Note: Data are from the in-home interviews of Waves II, III, and IV of Add Health. The symbol Δ represents the change in the values between two periods. Descriptions and definitions of the variables are given by Appendix Table A3. In columns (1) and (3), the dependent variables use the changes from Wave III to IV; in columns (2) and (4), the dependent variables use the changes from Wave II to III. "Overweight/Obesity" represents being overweight, obese, or both. Heteroskedasticity-robust standard errors are in parentheses. Longitudinal probability weights provided by Add Health are used. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4. Heterogeneities in the Joint Effects of Depression and Antidepressant Use on Body Weight

Dependent variables:	Δ BMI	Δ Overweight/Obesity
Subsamples:	(1)	(2)
Panel A: by gender		
Male (*N* = 1,922)	0.909	0.063
	(0.716)	(0.079)
Female (*N* = 1,831)	0.935	0.093
	(0.629)	(0.064)
Panel B: by body weight status at Wave III		
Overweight or obese (*N* = 1,656)	0.636	0.053***
	(0.788)	(0.017)
Neither overweight nor obese (*N* = 2,097)	1.236**	0.118
	(0.572)	(0.073)
Panel C: by income level		
Above or equal to the median of the personal earnings measured at Wave IV (*N* = 2,243)	1.014	0.050
	(0.716)	(0.069)
Below the median of the personal earnings measured at Wave IV (*N* = 1,510)	0.905	0.121*
	(0.671)	(0.068)
Panel D: by marital status		
Not married in Wave III, not married in Wave IV either (*N* = 2,114)	0.961*	0.151**
	(0.536)	(0.069)
Not married in Wave III, but married in Wave IV (*N* = 1,183)	0.582	-0.109
	(1.344)	(0.078)

Note: Data are from the in-home interviews of Waves III and IV of Add Health. The symbol Δ represents the change in the values between two periods. Descriptions and definitions of the variables are given by Appendix Table A3. In both columns, the dependent variables use the changes from Wave III to IV. "Overweight/Obesity" represents being overweight, obese, or both. In all panels, we include the same set of regressors as the ones in columns (1) and (3) of Table 3 except for Panel A, in which we also include the "pregnant" variable for the female-population regression. In Panel C, the median of the personal earnings measured at Wave IV (based on 15,127 observations in the full sample) is $30,000. Heteroskedasticity-robust standard errors are in parentheses. Longitudinal probability weights provided by Add Health are used. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Joint Effects of Depression and Antidepressant Use on Body Weight: Check on Potential Channels through Exercise and Fast Food Consumption

Dependent variable:	Δ BMI from Wave III to IV	Δ Overweight/Obesity from Wave III to IV
	(1)	(2)
Diagnosed with depression and taking antidepressant medications	1.005**	0.089*
	(0.478)	(0.050)
Δ Exercise	-0.042	-0.006
	(0.193)	(0.019)
Δ Fast food	0.038	-0.001
	(0.031)	(0.003)
Δ Age	0.221	0.001
	(0.177)	(0.018)
Δ College	0.288	0.007
	(0.287)	(0.021)
Δ Personal earnings	-0.002*	-0.000
	(0.001)	(0.000)
Δ Married	0.646***	0.033*
	(0.190)	(0.019)
Δ Smoking	-0.026***	-0.001
	(0.009)	(0.001)
Δ Drinking	-0.007	0.001
	(0.014)	(0.001)
Male	0.482**	0.080***
	(0.192)	(0.019)
White	0.533	0.086**
	(0.326)	(0.038)
Black	1.712***	0.185***
	(0.377)	(0.044)
Hispanic	0.334	0.099***
	(0.305)	(0.030)
Birth weight	0.000	0.004
	(0.092)	(0.008)
Not breastfed	0.455**	-0.022
	(0.187)	(0.020)
College education of either parents	-0.223	-0.023
	(0.185)	(0.020)
Biological mother being obese	0.744***	0.075***

	(0.282)	(0.026)
Biological father being obese	0.308	0.041
	(0.334)	(0.031)
BMI in Wave III	-0.019	-0.022***
	(0.022)	(0.001)
Constant	0.152	0.572***
	(1.288)	(0.142)
Observations	3,747	3,747

Note: Data are from the in-home interviews of Waves III and IV of Add Health. The symbol Δ represents the change in the values between two periods. Descriptions and definitions of the variables are given by Appendix Table A3. "Overweight/Obesity" represents being overweight, obese, or both. Heteroskedasticity-robust standard errors are in parentheses. Longitudinal probability weights provided by Add Health are used. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6. Robustness Checks on the Joint Effects of Depression and Antidepressant Use on Body Weight with Individual Fixed Effects Controlled for

Dependent variable:	Δ BMI			
	(1)	(2)	(3)	(4)
Diagnosed with depression and	1.007**	1.074**	1.029**	1.661***
taking antidepressant medications	(0.483)	(0.482)	(0.485)	(0.588)
Δ Age	0.196	0.210	0.210	0.318
	(0.176)	(0.177)	(0.176)	(0.440)
Δ College	0.296	0.286	0.287	-0.103
	(0.286)	(0.287)	(0.288)	(0.599)
Δ Personal earnings	-0.002	-0.002*	-0.002*	-0.014
	(0.001)	(0.001)	(0.001)	(0.012)
Δ Married	0.650***	0.637***	0.638***	1.185**
	(0.190)	(0.190)	(0.190)	(0.551)
Δ Smoking	-0.027***	-0.027***	-0.027***	-0.004
	(0.009)	(0.009)	(0.009)	(0.019)
Δ Drinking	-0.006	-0.005	-0.006	0.014
	(0.014)	(0.014)	(0.014)	(0.023)
Male	0.486**	0.490**	0.494**	0.518
	(0.192)	(0.192)	(0.192)	(0.521)
White	0.533	0.542*	0.537*	0.157
	(0.326)	(0.325)	(0.326)	(0.747)
Black	1.714***	1.731***	1.730***	1.988**
	(0.376)	(0.373)	(0.375)	(0.783)
Hispanic	0.351	0.337	0.333	0.684
	(0.305)	(0.307)	(0.307)	(1.007)
Birth weight	-0.002	0.001	0.003	0.180
	(0.092)	(0.092)	(0.092)	(0.188)
Not breastfed	0.457**	0.450**	0.451**	1.066**
	(0.187)	(0.187)	(0.187)	(0.500)
College education of either parents	-0.210	-0.227	-0.224	0.602
	(0.185)	(0.185)	(0.185)	(0.497)
Biological mother being obese	0.729***	0.715**	0.711**	1.308*
	(0.282)	(0.282)	(0.282)	(0.765)
Biological father being obese	0.330	0.334	0.334	0.771
	(0.334)	(0.336)	(0.335)	(1.043)
BMI in Wave III	-0.019	-0.019	-0.020	-0.007
	(0.022)	(0.022)	(0.022)	(0.044)
Δ CES-D (based on 9 items)		-0.035		
		(0.025)		

Δ Having major depression disorder symptoms			-0.306	
			(0.291)	
Constant	0.307	0.229	0.212	-2.979
	(1.288)	(1.288)	(1.288)	(3.317)
Observations	3,753	3,740	3,740	345

Dependent variable:	Δ Overweight/Obesity			
	(5)	(6)	(7)	(8)
Diagnosed with depression and taking antidepressant medications	0.092*	0.104**	0.099**	0.169**
	(0.050)	(0.050)	(0.050)	(0.068)
Δ Age	-0.003	-0.002	-0.002	-0.006
	(0.018)	(0.018)	(0.018)	(0.045)
Δ College	0.007	0.004	0.003	-0.080
	(0.021)	(0.021)	(0.021)	(0.070)
Δ Personal earnings	-0.000	-0.000	-0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.001)
Δ Married	0.034*	0.031*	0.030	0.028
	(0.019)	(0.019)	(0.019)	(0.056)
Δ Smoking	-0.002*	-0.002*	-0.001*	-0.002
	(0.001)	(0.001)	(0.001)	(0.002)
Δ Drinking	0.001	0.002	0.001	0.002
	(0.001)	(0.001)	(0.001)	(0.003)
Male	0.079***	0.079***	0.080***	0.068
	(0.019)	(0.019)	(0.019)	(0.060)
White	0.086**	0.088**	0.090**	0.110
	(0.038)	(0.038)	(0.038)	(0.120)
Black	0.188***	0.192***	0.196***	0.323**
	(0.044)	(0.044)	(0.044)	(0.135)
Hispanic	0.101***	0.097***	0.096***	0.148
	(0.030)	(0.030)	(0.030)	(0.106)
Birth weight	0.004	0.004	0.005	0.013
	(0.008)	(0.008)	(0.008)	(0.021)
Not breastfed	-0.024	-0.024	-0.023	-0.037
	(0.020)	(0.020)	(0.020)	(0.062)
College education of either parents	-0.023	-0.026	-0.026	0.063
	(0.020)	(0.020)	(0.020)	(0.070)
Biological mother being obese	0.068***	0.068**	0.065**	0.108
	(0.027)	(0.026)	(0.026)	(0.079)
Biological father being obese	0.045	0.045	0.046	0.056
	(0.031)	(0.031)	(0.031)	(0.111)
BMI in Wave III	-0.022***	-0.022***	-0.022***	-0.019***
	(0.001)	(0.001)	(0.001)	(0.004)
Δ CES-D (based on 9 items)		-0.007***		
		(0.003)		

Δ Having major depression disorder symptoms			-0.097***	
			(0.030)	
Constant	0.594***	0.593***	0.586***	0.372
	(0.144)	(0.142)	(0.142)	(0.388)
Observations	3,753	3,740	3,740	345

Note: Data are from the in-home interviews of Waves III and IV of Add Health. The symbol Δ represents the change in the values from Wave III to Wave IV. Descriptions and definitions of the variables are given by Appendix Table A3. Columns (1) and (5) are the same as columns (1) and (3) of Table 3. Columns (4) and (8) are based on the sample excluding those who did not take antidepressants and who did not have major depressive disorder symptoms (that is, the sample including those who took antidepressants or who had major depressive disorder symptoms). "Overweight/Obesity" represents being overweight, obese, or both. Heteroskedasticity-robust standard errors are in parentheses. Longitudinal probability weights provided by Add Health are used. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. Changes in the Population Rates in Overweight/Obesity and Antidepressant Use among Young Adults between 1988 and 2008

	Overweight/Obesity		Depression cases treated with antidepressants		Increase in the overweight/obesity rate from previous period due to change in the rate of depression with antidepressant use from the same previous period	
Period	Rate (%)	Percentage point increase from previous period	Rate (%)	Percentage point increase from previous period	Percentage point increase in the overweight/obesity rate due to antidepressant use	Percentage point increase in the overweight/obesity rate due to antidepressant use relative to the percentage point increase in the overweight/obesity rate
1988–1994	42.25	n/a	0.36	n/a	n/a	n/a
1999–2000	55.15	12.90	1.81	1.45	0.092 (from Table 3) ×1.45 ≈ 0.133	0.133/12.90 ≈ 1.031%
2007–2008	58.05	2.90	1.96	0.15	0.092 (from Table 3) ×0.15 ≈ 0.014	0.014/2.90 ≈ 0.483%

Note: Overweight and obesity data are from Ogden et al. (2010). Depression and antidepressant use data are from Olfson et al. (2002) and Marcus et al. (2007).

Appendix Table A1. Constructions of Samples for Regression Analyses

Data Source	Original sample size	Sample selection procedure	Sample size for regression analysis
Sample based on prescription medication use data			
Wave IV in-home interview	10,711 medications coming from 5,820 medication users	242-xxx-xxx (the nine-digit therapeutic classification code for psychotherapeutic agents)	1,145 medications (242-xxx-xxx) coming from 981 medication users; among these medications, there are three categories: 1) 832 users who use antidepressants (242-249-xxx) only; 2) 77 users who use antipsychotics (242-251-xxx) only; and 3) 72 users who use both antidepressants and antipsychotics.
		242-249-xxx (the nine-digit therapeutic classification code for antidepressants)	977 medications (242-249-xxx) coming from 904 medication users. Note that there are two categories: 1) 832 users who use antidepressants (242-249-xxx) only; and 2) 72 users who use both antidepressants and antipsychotics (243-251-xxx).
		242-251-xxx (the nine-digit therapeutic classification code for antipsychotics)	168 medications (242-251-xxx) coming from 149 medication users. Note that there are two categories: 1) 77 users who use antipsychotics (242-251-xxx) only; and 2) 72 users who use both antidepressants (242-249-xxx) and antipsychotics.
		two categories dropped: 1) 77 users who use antipsychotics (242-251-xxx) only; and 2) 72 users who use both antidepressants (242-249-xxx) and antipsychotics	832 users, kept in the sample for antidepressant analysis, who use antidepressants (242-249-xxx) only
Sample based on data from Wave III and IV			
Wave III and IV in-home interviews combined	30,898 observations from 17,864 respondents	313 invalid records were dropped, because there should be no antidepressant prescription medication without diagnosis first.	30,585 observations from 17,799 respondents
		43 observations were dropped, because of missing data on depression diagnosis or antidepressant use.	30,542 observations from 17,789 respondents

1,585 observations were dropped: we drop those who were diagnosed with depression or who had no diagnosis information in Wave III. Once we drop these observations and for the remaining ones in Wave III, we can assume that antidepressant medication in the last four weeks is zero.	28,957 observations (13,476 from Wave III and 15,481 from Wave IV) from 17,586 respondents. There are 13,476 respondents in Wave III; none of these respondents were diagnosed with depression. There are 15,481 respondents in Wave IV; among these respondents, 2,406 were diagnosed with depression, and 13,075 were not diagnosed with depression. Among those who were diagnosed with depression (2,406 respondents), 615 used antidepressant medications, and 1,791 did not use antidepressant medications. Among 13,476 respondents in Wave III, 8,333 have nonmissing longitudinal probability weights provided by Add Health. Among 15,481 respondents in Wave IV, 9,296 have nonmissing longitudinal probability weights provided by Add Health.

Note: Detail about the study design of Add Health is provided at http://www.cpc.unc.edu/projects/addhealth/design.

Appendix Table A2. Percentiles of Body Mass Index Distribution for Children Ages 11-20 Years

Age	95th Percentile BMI Value		85th Percentile BMI Value		5th Percentile BMI Value	
(in years)	Male	Female	Male	Female	Male	Female
11	23.21358	24.14141	20.19667	20.86984	14.56001	14.40290
12	24.22985	25.25564	21.02386	21.74263	14.97745	14.83262
13	25.17811	26.29880	21.85104	22.57506	15.45918	15.30749
14	26.04662	27.25597	22.66325	23.34689	15.99065	15.80753
15	26.83688	28.12369	23.45117	24.04503	16.55481	16.30974
16	27.56393	28.90981	24.21087	24.66372	17.13250	16.78787
17	28.25676	29.63350	24.94362	25.20482	17.70284	17.21234
18	28.95862	30.32554	25.65601	25.67786	18.24349	17.55015
19	29.72674	31.02880	26.36054	26.09993	18.73019	17.76515
20	30.58964	31.76474	27.04607	26.47872	19.12055	17.82009

Note: Body Mass Index (BMI) is calculated using the following formula: BMI = weight (in kilograms)/height (in meters)^2 or BMI = 703*weight (in pounds)/height (in inches)^2. According to the distributions given in the Growth Charts of the Centers for Disease Control and Prevention (CDC), for children ages 2-20 years, "obese" is defined to be ≥ 95th percentile of BMI for the appropriate age-sex group; "overweight" is defined to be ≥ 85th percentile of BMI and < 95th percentile of BMI for the appropriate age-sex group; "normal weight" is defined to be ≥ 5th percentile and < 85th percentile of BMI for the appropriate age-sex group; "underweight" is defined to be < 5th percentile of BMI for the appropriate age-sex group. For both male and female adults aged at least 21 years, "obese" is defined to be BMI ≥ 30, "overweight" to be BMI ≥ 25 and BMI < 30, "normal weight" to be BMI ≥ 18.5 and BMI < 25, "underweight" to be BMI < 18.5. This table is reproduced from CDC. More details are provided in the following website: http://www.cdc.gov/growthcharts/html_charts/bmiagerev.htm.

Appendix Table A3. Descriptions and Definitions of Variables

Variables	Descriptions and Definitions
BMI	Body Mass Index (detail provided in Appendix Table 2)
Obese	equal to 1 if obese and 0 otherwise (detail provided in Appendix Table 2)
Overweight	equal to 1 if overweight and 0 otherwise (detail provided in Appendix Table 2)
Normal weight	equal to 1 for optimal weight and 0 otherwise (detail provided in Appendix Table 2)
Underweight	equal to 1 if underweight and 0 otherwise (detail provided in Appendix Table 2)
Diagnosed with depression	equal to 1 if ever diagnosed with depression by a doctor, nurse or other health care provider and 0 otherwise
Antidepressant medication	equal to 1 if taking antidepressant medications in the last four weeks and 0 otherwise (detail provided in Appendix Table 1)
Diagnosed with depression and taking antidepressant medications	equal to 1 if ever diagnosed with depression and also taking antidepressant medications in the last four weeks, and equal to 0 otherwise
Diagnosed with depression but without antidepressant medications	equal to 1 if ever diagnosed with depression and also not taking antidepressant medications in the last four weeks, and equal to 0 otherwise
CES-D (based on 9 items)	range: 0-27
Having major depressive disorder symptoms	equal to 1 (or 0) if CES-D $\geq$ 10 (or CES-D < 10) for males; equal to 1 (or 0) if CES-D $\geq$ 11 (or CES-D < 11) for females
Having health insurance or not at the time of the interview	equal to 1 (or 0) if having (or not having) health insurance at the time of the interview
Age	age in years
College	equal to 1 if having some college (or higher) education and 0 otherwise
Personal earnings	For Wave III, it is the income received in 2000/2001 from personal earnings (in $1,000 and calculated using the midpoint of the range given by the survey questionnaire) before tax (that is, wages or salaries, including tips, bonuses, and overtime pay, and income from self-employment). For Wave IV, it is the income received in 2006/2007/2008 from personal earnings (in $1,000 and calculated using the midpoint of the range given by the survey questionnaire) before tax (that is, wages or salaries, including tips, bonuses, and overtime pay, and income from self-employment).
Currently working for pay	equal to 1 if currently working for pay for at least 10 hours a week and equal to 0 otherwise

Married	equal to 1 if currently married and living together (not separated) and equal to 0 otherwise
Pregnant	equal to 1 if currently pregnant and 0 otherwise
Smoking	the number of days smoking in the past 30 days
Drinking	the number of days drinking alcohol in the past 30 days
Exercise	equal to 1 (or 0) if had (or had no) physical exercise in the past seven days
Fast food	the number of days (for Waves III) or times (for Wave IV) eating at fast food restaurants in the past seven days
Male	equal to 1 (or 0) if male (or female)
White	equal to 1 if White and 0 otherwise
Black	equal to 1 if Black and 0 otherwise
Hispanic	equal to 1 if Hispanic and 0 otherwise
Asian	equal to 1 if Asian and 0 otherwise
Native	equal to 1 if Native and 0 otherwise
Birth weight	birth weight (in pounds) reported by parents
Not breastfed	equal to 1 if not breastfed and equal to 0 if breastfed
College education of either parents	equal to 1 if either of parents has some college (or higher) education and equal to 0 otherwise
Biological mother being obese	equal to 1 if biological mother is obese and 0 otherwise
Biological father being obese	equal to 1 if biological father is obese and 0 otherwise

Note: Variables are obtained from Waves III and IV questionnaires of Add Health. Questionnaires are available at the following website:
http://www.cpc.unc.edu/projects/addhealth/codebooks.

Appendix Table A4. Joint Effects of Depression and Antidepressant Use on Body Weight with Individual Fixed Effects and Additional Time-Varying Characteristics Controlled for

Dependent variable:	Δ BMI		Δ Overweight/Obesity	
	Main result	Falsification check	Main result	Falsification check
	(1)	(2)	(3)	(4)
Diagnosed with depression and taking antidepressant medications	1.077**	0.169	0.100*	-0.036
	(0.494)	(0.436)	(0.051)	(0.058)
Δ Age	0.222	-0.278**	-0.002	-0.011
	(0.179)	(0.135)	(0.018)	(0.019)
Δ College	0.268	0.448**	0.005	-0.009
	(0.290)	(0.185)	(0.021)	(0.024)
Δ Personal earnings	-0.003*	-0.000	-0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
Δ Married	0.610***	-0.327**	0.033*	0.010
	(0.196)	(0.142)	(0.019)	(0.020)
Δ Smoking	-0.027***	0.008	-0.001*	0.001
	(0.009)	(0.007)	(0.001)	(0.001)
Δ Drinking	-0.006	-0.032***	0.001	-0.003*
	(0.015)	(0.009)	(0.001)	(0.001)
Δ Having health insurance or not at the time of the interview	0.345	-0.054	-0.003	0.030
	(0.248)	(0.144)	(0.019)	(0.020)
Δ Currently working for pay	-0.152	-0.093	0.002	-0.020
	(0.179)	(0.114)	(0.015)	(0.015)
Male	0.510**	-0.012	0.082***	0.012
	(0.201)	(0.146)	(0.019)	(0.019)
White	0.532	-0.590*	0.091**	-0.049
	(0.329)	(0.303)	(0.039)	(0.036)
Black	1.787***	-0.347	0.193***	0.018
	(0.379)	(0.338)	(0.045)	(0.044)
Hispanic	0.321	-0.136	0.105***	-0.012
	(0.315)	(0.249)	(0.030)	(0.035)
Birth weight	-0.004	0.052	0.004	0.018**
	(0.092)	(0.063)	(0.008)	(0.009)
Not breastfed	0.469**	0.083	-0.023	0.047**
	(0.188)	(0.148)	(0.020)	(0.021)
College education of either parents	-0.164	-0.227	-0.019	0.018
	(0.185)	(0.152)	(0.020)	(0.021)

Biological mother being obese	0.745***	-0.034	0.072***	0.014
	(0.286)	(0.220)	(0.027)	(0.027)
Biological father being obese	0.247	1.261***	0.049	0.028
	(0.339)	(0.263)	(0.032)	(0.031)
BMI in Wave III	-0.016		-0.022***	
	(0.023)		(0.001)	
BMI in Wave II		-0.021		-0.011***
		(0.021)		(0.001)
Constant	0.052	5.722***	0.591***	0.342**
	(1.313)	(1.091)	(0.145)	(0.142)
Observations	3,703	3,690	3,703	3,690

Note: Data are from the in-home interviews of Waves II, III, and IV of Add Health. The symbol Δ represents the change in the values between two periods. Descriptions and definitions of the variables are given by Appendix Table A3. In columns (1) and (3), the dependent variables use the changes from Wave III to IV; in columns (2) and (4), the dependent variables use the changes from Wave II to III. "Overweight/Obesity" represents being overweight, obese, or both. Heteroskedasticity-robust standard errors are in parentheses. Longitudinal probability weights provided by Add Health are used. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.