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Peer effects in adolescent overweight☆

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ABSTRACT

This study is the first to estimate peer effects for adolescent weight. We use data from the National Longitudinal Study of Adolescent Health (Add Health) and define peer groups using nominated friends within schools. Endogenous peer groups are accounted for using a combination of school fixed effects, instrumental variables, and alternative definitions of peers (i.e., grade-level peers). Mean peer weight is correlated with adolescent weight, even after controlling endogenous peer groups. The impact of peer weight is larger among females and adolescents with high body mass index. The results are consistent with social multipliers for adolescent overweight policies.

1. Introduction

The prevalence of overweight in children, the term used to define childhood obesity, has increased dramatically over the last 40 years. The prevalence of overweight among children and adolescents was four times higher in 2002 than in the 1960s (16% vs. 4%) (Hedley et al., 2004). As a result, interest in identifying the causes of this trend and policies for reducing childhood overweight is growing.

Research on the determinants of childhood overweight has focused on parental influences, the role of food prices, the built environment, and school nutrition policies (Koplan et al., 2005). One area that has not received much attention to date is the role of peers in determining adolescent weight. The existing literature on peer effects suggests that peers influence other health behaviors among youth, including smoking, alcohol and drug use (Evans et al., 1992; Norton et al., 1998; Gaviria and Raphael, 2001; Powell et al., 2005; Lundborg, 2006; Clark and Loheac, 2007). Regarding attitudes and weight-related behaviors, the psychology and medical literature has shown that social influences impact norms for perceived obesity and that peer involvement in weight loss programs is effective (Paxton et al., 1999; Wing and Jeffery, 1999; Jelalian and Mehlenbeck, 2002; Eisenberg et al., 2005). In addition, new evidence among adults suggests that obesity spreads through social ties (Christakis and Fowler, 2007). However, there is no literature on the impact of peer effects on adolescent weight.[1]

This study seeks to estimate peer effects for adolescent weight. There are several reasons to believe that one's peers can affect weight. Peers can influence a variety of weight-related choices including healthy and unhealthy eating patterns (e.g.,

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[1] Strauss and Pollack (2003), using the same data as this study, investigate the influence of adolescent weight on adolescent social networks, but not the impact of the network's weight on the adolescent. Our focus is the latter effect.

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cafeteria vs. snack shop), dieting, and physical activity (e.g., extra-curricular sports). Peers can also affect perceptions of acceptable weight (e.g., Crawford and Campbell, 1999).

Burke and Heiland (2007) develop a theoretical model of optimal weight that incorporates this kind of social dynamic. They extend the models of optimal weight by Lakdawalla and Philipson (2002) and Cutler et al. (2003) by making ideal weight in the utility function an endogenous function of the average weight of the social reference group. In their model, the target weight is a fraction of average weight in the peer group; people desire to be thinner than average. As their peers gain weight, they can gain weight and achieve a higher level of utility. This model provides a theoretical link explaining how the weight of one's peers can indirectly *cause* weight gain at the individual level.

If peers do have an influence in determining adolescent weight, then policies aimed at reducing adolescent overweight could have social multiplier effects where the impact of the policy in the aggregate is larger than for individual participants (Glaeser et al., 2002; Christakis and Fowler, 2007).

We use data from the National Longitudinal Study of Adolescent Health (Add Health) to estimate the influence of peer weight on adolescent's own weight. Add Health allows us to define peer groups using nominated friendship relationships. Few other studies have been able to define peer groups at such a fine level (one exception is Clark and Loheac, 2007, who also use Add Health to examine peer effects for smoking, alcohol and marijuana). While friends might be more influential than other common definitions of peer groups such as all students in a school,[2] friends' weight is likely to be endogenous. We address this using three strategies. First, we look at variation in peer-group weight within schools. Second, we use information on friends' parents' obesity and health and friends' birth weight to instrument for peers' weight. The identifying assumption is that friends' birth weight and friends' parental obesity and health only affects an adolescent's weight through its effect on friends' weight. Third, we alternatively define peer groups using all students in the same grade. After controlling for school fixed effects, peers defined at the grade level are plausibly exogenous (Clark and Loheac, 2007).

Our results suggest that peer effects exist for adolescent weight. The impact of peer weight is larger among females and adolescents with high body mass index (kg/m^2; BMI). The results do not rule out social multipliers for childhood and adolescent overweight policies.

The paper is organized as follows. Section 2 discusses the estimation of peer effects and our identification strategy. Section 3 describes the data and our specification. Section 4 presents the main results and sensitivity analysis. Section 5 concludes.

2. Estimating peer effects

Using Manski's (1993) framework, peers' weight could be correlated with an adolescent's weight in observational data because (1) peers' weight influences adolescent weight directly (endogenous or causal effects), (2) peers' characteristics other than weight influence adolescent weight (exogenous or contextual effects), or (3) a common set of unobserved characteristics influence both own and peer weight (correlated effects). The goal of this analysis is to identify the causal effects of peers' weight on adolescent weight through the types of mechanisms described above (e.g., peers' weight determining target weight).

Contextual effects are present if peers' characteristics such as income or race/ethnicity influence adolescent weight. We follow the existing literature and assume that there are no contextual effects (Norton et al., 1998; Gaviria and Raphael, 2001; Powell et al., 2005). The assumption is that any influence peers might have on adolescent weight is through their own weight.[3]

There are three primary sources of correlated effects for friendship peer groups. First, any school policy that affects diet or exercise and is shared by all students will lead to correlated effects. Second, families might endogenously sort into areas and schools based on unobserved factors leading students within schools to look similar. It seems unlikely that selection of school district would be based on adolescent weight, but it could be based on amenities plausibly correlated with adolescent weight such as the availability of recreation areas and grocery stores. Third, even within schools, friends are likely to share common activities (e.g., sports) that are unobserved to an econometrician. Accounting for these effects is important because if correlation between adolescent weight and peers' weight is due to contextual or correlated effects, policies that reduce adolescent overweight would not lead to social multipliers.

We use three strategies to control for correlated effects and identify causal effects of peers' weight on adolescent weight. First, we include school fixed effects in all of our specifications. Looking within schools to identify peer effects eliminates the influence of any unobserved school or neighborhood amenities that might lead to sorting of families into schools (Arcidiacono and Nicholson, 2005). We also control directly for whether parents report the school system as being important in the decision to live in their neighborhood. School fixed effects also control for any shared influences at the school level such as school lunch policies or physical education requirements (Clark and Loheac, 2007).

Second, we instrument friends' weight using information about friends' birth weight, friends' parents' obesity, and friends' parents' self-reported health status. Peer-group characteristics have been used previously as instruments for peer behavior among youth (Gaviria and Raphael, 2001; Powell et al., 2005). Under the assumption that background characteristics of peers

[2] Bearman and Brückner (1999) summarize findings from Add Health for sexual behavior and find that peers at the school as a whole had little impact on female sexual behavior.

[3] See Section 4 for supporting evidence of this assumption.

have no direct influence on an adolescent's weight but only indirectly influence adolescent weight through their impact on peer weight these variables are valid instruments.[4] This identifying assumption will be violated if the selection of friends, and by implication the selection of friends' parents, is correlated with BMI. In that case, friends' parental characteristics will still be correlated with the error term in the main equation.

Third, we consider an alternative definition of peer groups: students within the same grade level (Clark and Loheac, 2007). Conditional on school fixed effects, the assignment to grade level is determined exogenously by year of birth. While peer groups defined using grade levels are more exogenous than those defined using friends, they are not necessarily expected to generate the same peer effects. Conceptually, grade-level peer effects are likely to operate through different causal mechanisms than friend-level peer effects (see Brown and Theobald, 1999). For example, broader measures of social networks could operate through the establishment of BMI norms and a reference BMI for body image concerns (e.g., Burke and Heiland, 2007), while more proximal measures of peer effects could operate through influences on diet and physical activity behavior. Empirically, using all students in the same grade could attenuate the estimated effect of peers on adolescent weight by including students outside the relevant social network of influence. For instance, Christakis and Fowler (2007) found that the influence of the weight of friends, family and neighbors decreases as the degree of separation from the person increased. On the other hand, as described below, the data permit only incomplete matches between listed friends resulting in measurement error in friends' weight, which would also tend to bias the estimated peer effect using friends downward.

3. Data and empirical specification

We use data from Wave I of the National Longitudinal Study of Adolescent Health (Add Health) collected in 1994 and 1995 (Udry, 2003). Add Health is a nationally representative, school-based survey of youth in grades 7 through 12. One of the unique features of this data is that students were asked to list up to 10 of their closest friends (5 male and 5 female), which allows us to define peer groups at the level of friends. Data for Add Health was collected in three groups of students. The In-School sample, nearly 90,118 students, was asked to complete one questionnaire. A smaller Wave I In-Home sample ($N = 20{,}745$) was drawn randomly from within each school and received a more extensive questionnaire, which included questions on height and weight and interviews with parents. The same questionnaire used in the In-Home sample was also given to every student in 16 selected schools (Saturation sample; $N = 3702$).[5]

Because the In-Home sample was a random sample of students from each school, it is not possible to match responses from every friend listed by each student. In order to better capture the peer group, this study focuses on the Saturation sample. The estimation sample consists of adolescents for whom we can match at least one friend's weight ($N = 2800$).[6] Additional sensitivity analysis is conducted using 6451 students who received the Wave I In-Home survey for whom we can match at least one of their friends' weights.

The dependent variables of interest are BMI constructed using self-reported height and weight and an indicator variable for being overweight.[7] The 2000 Centers for Disease Control and Prevention Growth Charts for the United States are used to categorize adolescents as overweight (Kuczmarski et al., 2002). The categories are based on the adolescent's BMI relative to the national distribution of BMI for adolescents based on historical National Health Examination Surveys (NHES) and National Health and Nutrition Examination Surveys (NHANES) (Himes and Dietz, 1994). Typically, adolescents in the 95th percentile and over of BMI are classified as overweight; those in the 85–94th percentile are classified as at-risk; those in the 5–84th are classified as normal weight; and those below the 5th percentile are classified as underweight. We define an indicator variable for being at the 85th percentile and higher (i.e., at-risk and overweight) and will refer to this as overweight for simplicity. Because the cutoffs are based on historical data, it is possible that more than 15% of the current sample is categorized as overweight.

The model for BMI of adolescent i with peer group j in school s is

$$\mathrm{BMI}_{ijs} = \beta_0 + \beta_1 \mathrm{BMI}_{js} + \beta_2 X_{is} + \delta_s + \varepsilon_{is}$$

The main variable of interest is the mean weight among peers (BMI_{js}). The control variables (X_{is}) include adolescent characteristics and family/household characteristics and are described below. All estimated models also include school fixed effects (δ_s). Probit analysis is used to analyze the probability of overweight status using the same specification except replacing BMI_{js} with the proportion of peers that are overweight.

[4] Background characteristics of peers could have a direct effect on adolescent weight if the adolescent was exposed to the peers' family (e.g., regularly eating dinner at a peer's home) or if the adolescent's parents were influenced by a peer's family and subsequently affected their adolescent child's weight. We conduct over-identification tests for the instruments and also report results for an alternative definition of peers (see below).

[5] The 16 schools are composed of two large schools and 14 small schools. One of the large schools is predominantly white and located in a small town; the other is racially mixed and is located in a major metropolitan area. The 14 smaller schools are a mix of urban and rural, public and private schools.

[6] Adolescents who do not list any friends or for whom no friends have BMI information are excluded in the analysis using friends as the peer group. These students are included in the analysis using students in the same grade as the peer group.

[7] Goodman et al. (2000) investigate the relationship between self-reported height and weight and measured height and weight in later waves of Add Health and find that BMI generated using self-reported height and weight, the only available measures in Wave I, is highly correlated with BMI generated using measured height and weight ($r = 0.92$) and correctly classifies 96% as to obesity status.

The adolescent characteristics in the regression models include: gender, age, race/ethnicity (white [omitted], black, Hispanic, other), religion (indicator for religion being "very" or "fairly" important), smoking status (indicator for smoking in last 30 days), birthweight, and general health (indicator for self-reported health status of "excellent," "very good," or "good"). The family/household characteristics include: parental obesity (indicators for whether the mother and father are obese), household income (in $20,000 interval categories), parental education (less than high school [omitted], high school or GED, some college, and college or higher degree), parental work status (indicator for working parents), parental religion (for religion being "very" or "fairly" important), parental general health (indicator for self-reported health status of "excellent," "very good," or "good"),[8] smoking in household, parental marital status (indicator for married), whether the parents reported to have chosen the neighborhood specifically because of the schools, indicator for whether parents let the adolescent make his/her own decisions about what to eat, and the number of evenings in the past week that at least one parent was in the room during the adolescent's dinner. With the exception of the last two variables, all family/household characteristics are taken from the parental survey. Rather than dropping observations for missing values of the control variables, we include indicators for missing values where necessary.[9]

Adolescents are likely to have shared influences with their friends in ways both observed and unobserved to the econometrician. We use instrumental variable estimation (two-stage least squares [2SLS] for BMI and instrumental variable probit [IV-probit] for overweight status) to control for this type of endogeneity. Add Health provides a number of variables for peers that are supported by the literature as being predictive of peers' weight and that are plausibly exogenous to the adolescent's own weight: mean peer birth weight, proportion of peers whose parents are obese, and mean parental health of peers. For the instrumental variables, missing indicators are used when the variable is missing for all listed friends.

The instruments will violate the exclusion restriction if the selection of friends is correlated with BMI. Therefore, we also conduct the analysis with peers defined as all students in the same grade within the same school as the adolescent. Within school, these peer groups are exogenously determined by age. The estimation sample from the Saturated sample is larger for this peer-group definition because we no longer have to match friends ($N = 3554$).

Quantile regression is used to determine whether the influence of mean BMI among peers has different affects among adolescents in different parts of the conditional BMI distribution (conditional on covariates X). If adolescents in the upper tail of the conditional BMI distribution are more affected by peer weight, increases in adolescent weight would generate more feedback at high BMI levels and thus increase in the number of adolescents in the right tail of the BMI distribution, consistent with the trends in the adolescent BMI distribution over the last few decades. Quantile regressions for the 25th, 50th, and 75th percentiles of the conditional BMI distribution are estimated using the same specification as in the OLS analysis. An analogue to 2SLS (Amemiya, 1982) is also estimated to account for the endogeneity of friends' weight using the same instruments as described above.

All analyses are conducted on the entire sample with matched friends as well as separately by sex to determine whether males or females are more influenced by their peers (Kling et al., 2005; Soetevent and Kooreman, 2006; Christakis and Fowler, 2007; Clark and Loheac, 2007). As a sensitivity check, the analyses are also repeated for alternative definitions of peer groups including students in the In-Home sample with matched friends and separate peer groups by gender within the same grade within the same school.

4. Results

4.1. Features of the estimation sample

The mean BMI in the Saturation sample is 22.9 (Table 1); 27% of adolescents in the sample are overweight (i.e., greater than the 85th percentile of historical growth charts). The prevalence of overweight is comparable to the prevalence of at-risk and overweight for 12–19-year olds in the National Health and Nutrition Examination Survey (NHANES; 30.9%), which uses measured height and weight to calculate BMI (Hedley et al., 2004). Many students nominated less than the maximum number of friends allowed; in the raw data the average number of nominated friends is 5.9 in the Saturation sample and 4.5 in the In-Home sample. Of those, the mean number of friends matched in the Saturation sample was 3.3. This is substantially higher than the number of friends that are able to be matched in the In-Home sample (2.1). The proportion of friends that are overweight is less than the overall sample proportion, indicating that overweight adolescents are less likely to be nominated as friends (Strauss and Pollack, 2003). The mean number of friends matched for overweight adolescents was slightly lower than for normal weight adolescents in the Saturation sample but not statistically different in the In-Home sample (not reported). When peers are defined as students in the same grade, the mean BMI and the proportion of grade overweight are similar to the overall sample averages.

8 Non-instrumental variable results are unaffected by including separate dummies for each self-reported health category for adolescent and parental health. The peer effects in the instrumental variable regressions fall slightly in magnitude but retain the same significance levels as the estimates reported below.

9 As a robustness check, we also imputed missing values using multiple imputation techniques, specifically imputation by chained equations. The results were quantitatively almost identical to those reported in the tables below and did not change the qualitative results at all. Results available upon request.

Table 1
Descriptive statistics for estimation samples

	Saturation sample	In-Home sample
Dependent variable		
Body mass index (kg/m^2; BMI)	22.9	22.6
Overweight	27.3%	26.5%
Key variables		
Mean BMI among friends	22.6	22.3
Proportion of friends overweight	23.9%	24.1%
Mean number of friends	3.3	2.1
Mean BMI among grade	23.0	22.6
Proportion of grade overweight	27.5%	27.0%
Other variables		
Age	16.1	15.7
Household income		
$20,000–$39,999	23.0%	21.3%
$40,000–$59,999	19.4%	18.6%
$60,000–$79,999	10.7%	9.7%
$80,000–$99,999	4.2%	4.6%
$100,000 and above	3.0%	5.4%
Income missing	29.0%	26.6%
Race/ethnicity		
White	50.5%	54.5%
Black	12.9%	18.0%
Hispanic	19.7%	16.1%
Other race	16.9%	11.1%
Missing	0.1%	0.3%
Religion is important	80.9%	78.8%
Religion is important (missing)	1.0%	1.3%
Current smoker	27.7%	25.8%
Current smoker (missing)	1.3%	1.0%
Health status (good, very good, excellent)	92.6%	93.2%
Health status missing	0.0%	0.0%
Biological mother obese	14.8%	14.7%
Biological mother obese (missing)	19.0%	16.7%
Biological father obese	8.4%	8.5%
Biological father obese (missing)	20.6%	18.9%
Birth weight (ounces)	86.2	89.1
Birth weight (missing)	27.8%	24.4%
Responding parent's education		
Less than high school	13.8%	13.1%
High school	25.0%	25.3%
Less than college	25.8%	25.2%
College degree or higher	17.3%	20.9%
Missing	18.1%	15.5%
Responding parent is employed	48.9%	49.0%
Responding parent is employed (missing)	19.1%	16.3%
Parent: religion is important	74.8%	75.7%
Parent: religion is important (missing)	18.1%	15.4%
Parent's health status (good, very good, excellent)	71.4%	73.0%
Parent's health status (missing)	18.3%	15.4%
Smoker in household	34.7%	36.9%
Smoker in household (missing)	18.3%	15.5%
Married	62.7%	63.0%
Marital status missing	18.0%	15.2%
Allowed to make own decisions about what to eat	79.8%	80.7%
Allowed to make own decisions about what to eat (missing)	1.6%	1.5%
Days at least one parent was in the room while eating dinner	4.3	4.5
Days at least one parent was in the room while eating dinner (missing)	1.6%	1.7%
Live in neighborhood because of schools	34.6%	40.1%
Live in neighborhood because of schools (missing)	19.6%	16.8%
Instruments-defined among friends		
Biological mother obese	15.1%	14.5%
Biological mother obese (missing)	6.6%	10.4%
Biological father obese	9.3%	8.8%
Biological father obese (missing)	7.1%	12.1%

Table 1 (*Continued*)

	Saturation sample	In-Home sample
Birth weight (ounces)	106.8	99.8
Birth weight (missing)	10.0%	15.4%
Parent's health status (good, v. good, excellent)	82.9%	79.2%
Parent's health status (missing)	6.1%	9.1%
Number of observations	2800	6451

Data from Wave I of the National Longitudinal Study of Adolescent Health (Add Health). The estimation sample includes all adolescents for whom data for nominated friends could be matched and at least one friend had information on BMI.

Obesity rates for parents of the adolescents in the sample appear to be lower than estimates found in NHANES (e.g., 15% vs. approximately 30%; Hedley et al., 2004). This is likely due to the fact that the obesity question in the Add Health parental questionnaire is phrased as suffering from a health problem rather than calculated from height and weight.[10]

4.2. Influence of friends' weight

The results indicate that friends' weight is correlated with an adolescent's own weight even after controlling for such things as demographics, smoking status, birth weight, and own parental and household characteristics including parental obesity. The OLS estimates indicate that when the mean weight of an adolescent's friends is 1 BMI unit higher, adolescent weight is higher by 0.3 BMI units (Table 2).[11] The marginal effect of the proportion of friends overweight on one's own probability of being overweight is 0.2.

Results for other variables indicate that males tend to have higher BMI and a higher probability of being overweight. Older adolescents tend to have higher BMI but are less likely to be overweight. Adolescents who rate general health better are associated with lower levels of BMI and a lower probability of being overweight. Adolescents with obese parents are much more likely to have higher BMI and higher probability of being overweight themselves. Finally, having a smoker in the household and parents who are present more often during dinner are positively associated with higher BMI but not higher probability of being overweight. None of the other variables in the models are statistically significant, including the race/ethnicity, income, and smoking.[12,13] The peer-group coefficients are the focus for the rest of the study.

Peer weight remains positive and statistically significant in the instrumental variable estimates as well. The 2SLS estimates indicate that when the mean weight of an adolescent's friends is 1 BMI unit higher, adolescent weight is higher by 0.65 BMI units. The marginal effect of the proportion of friends overweight on one's own probability of being overweight is 0.39. The instruments are strongly correlated with peer weight in the first stage; the F tests for the instruments in the first stage are 18.65 ($p < 0.001$) and 14.30 ($p < 0.001$), respectively, for the 2SLS and IV-probit specifications. Based on the critical values provided by Stock and Yogo (2005), the first stage F statistic of 18.65 with eight excluded instruments is large enough to restrict the bias of the 2SLS to less than 10% of the OLS bias. An Anderson–Rubin test (Anderson and Rubin, 1949), which is robust to weak instruments assuming that the over-identification restrictions are valid, rejects the null hypothesis that the 2SLS coefficient on the peer group is zero ($p = 0.003$). The instruments also pass over-identification tests; we fail to reject the null hypothesis that, conditional on the assumption that a subset of instruments are valid, the remaining instruments are orthogonal to the error term from the first equation, which supports their use as instruments.

We repeat the analysis using friends as the peer group in the Saturation sample separately for males and females (Table 3). The estimated marginal effects for the peer group on BMI are similar for both males and females. However, the probability of overweight in females appears more sensitive to the overweight status of peers than the effect of peers among males.

4.3. Who is being influenced?

Adolescents at the higher end of the conditional BMI distribution are more influenced by mean weight among friends than adolescents at the lower end of the conditional BMI distribution (Table 4). For example, the instrumental variable estimates in the overall Saturated sample suggest that when mean BMI among friends is 1 BMI unit higher, adolescent BMI is higher

[10] The question is worded as follows: "This group of questions are about health problems. For each of the following health problems, please tell me whether {[adolescent's] NAME} has it now. Also please tell me whether (his/her) biological mother or (his/her) biological father has it now." Obesity is included in a list of health problems that also includes migraine headaches, allergies, asthma or emphysema, alcoholism, and diabetes.

[11] For a 16-year-old of average height, one BMI unit is approximately 6 pounds; 0.3 BMI units are just under two pounds.

[12] The lack of significance from these variables is the result of two factors. First, most of the minorities in the Saturation sample are from one large, urban school. These minorities are not representative of the nation. Second, the reported results control for several genetic and environmental factors. In a pared down specification that includes only mean peer BMI, sex, age, income, race/ethnicity, and smoking status, Hispanic ethnicity and current smoking were both significantly positively correlated with adolescent BMI. (The OLS coefficient on mean friends' BMI was 0.35 compared to 0.30 in Table 2.)

[13] We tested for possible contextual effects by including in the OLS specifications peers' parents' education level, peers' mean household income, and peers' racial composition. In the friend specifications none of the other contextual effects were statistically significant, individually or jointly. In the grade-level specifications, racial composition was statistically significant, but as a whole the contextual effects were jointly insignificant.

Table 2
The effects of friends' weight on adolescent weight

Variable	Dependent variable			
	BMI		Probability of overweight	
	OLS	IV	Probit	IV-Probit
Mean BMI among friends	0.30** (0.03)	0.52** (0.11)		
Proportion of friends overweight [marginal effect]			0.65** (0.08) [0.21]	1.54** (0.43) [0.39]
Male	0.67** (0.16)	0.63** (0.16)	0.21** (0.05)	0.20** (0.06)
Age	0.28** (0.07)	0.22** (0.07)	−0.08** (0.02)	−0.07** (0.02)
Income (ref: <$20,000)				
$20,000–$39,999	0.10 (0.30)	0.09 (0.30)	0.00 (0.10)	−0.00 (0.10)
$40,000–$59,999	−0.06 (0.32)	−0.11 (0.33)	−0.10 (0.11)	−0.12 (0.11)
$60,000–$79,999	−0.16 (0.38)	−0.10 (0.38)	−0.06 (0.13)	−0.05 (0.13)
$80,000–$99,999	0.69 (0.49)	0.77 (0.49)	0.19 (0.16)	0.20 (0.17)
$100,000+	0.75 (0.55)	0.78 (0.55)	0.20 (0.18)	0.20 (0.19)
Income missing	−0.11 (0.35)	−0.12 (0.35)	−0.19 (0.12)	−0.19 (0.12)
Race/ethnicity (ref: white)				
Black	0.42 (0.41)	0.33 (0.41)	−0.14 (0.14)	−0.13 (0.14)
Hispanic	0.39 (0.39)	0.37 (0.39)	−0.12 (0.13)	−0.12 (0.13)
Other	−0.18 (0.40)	−0.10 (0.40)	−0.26 (0.14)	−0.20 (0.14)
Missing	0.19 (2.39)	0.50 (2.40)		
Religion is important	0.22 (0.23)	0.25 (0.23)	0.03 (0.08)	0.05 (0.08)
Religion is important (missing)	−0.40 (0.80)	−0.44 (0.80)	−0.05 (0.27)	−0.01 (0.27)
Current smoker	0.29 (0.19)	0.28 (0.19)	0.02 (0.07)	0.02 (0.07)
Current smoker (missing)	−0.02 (0.70)	0.02 (0.70)	−0.07 (0.23)	−0.04 (0.24)
Health status	−2.78** (0.30)	−2.67** (0.31)	−0.63** (0.10)	−0.57** (0.10)
Biological mother obese	1.59** (0.24)	1.55** (0.24)	0.29** (0.08)	0.28** (0.08)
Biological mother obese (missing)	2.22** (0.57)	2.22** (0.57)	0.66** (0.19)	0.69** (0.20)
Biological father obese	1.80** (0.30)	1.62** (0.32)	0.46** (0.10)	0.40** (0.10)
Biological father obese (missing)	−0.62 (0.49)	−0.67 (0.49)	−0.26 (0.17)	−0.30 (0.18)
Birth weight (oz.)	0.005 (0.005)	0.004 (0.005)	0.00 (0.00)	0.002 (0.002)
Birth weight (missing)	0.16 (0.64)	−0.04 (0.65)	0.24 (0.22)	0.14 (0.23)
Parental education (ref: less than high school)				
High school	0.37 (0.29)	0.32 (0.30)	0.03 (0.10)	0.00 (0.10)
Less than college	−0.05 (0.30)	−0.06 (0.30)	−0.10 (0.10)	−0.10 (0.11)
College	−0.01 (0.34)	0.04 (0.35)	−0.19 (0.12)	−0.18 (0.12)
Missing	0.83 (1.44)	1.11 (1.45)	−0.38 (0.58)	−0.31 (0.59)
Parent employment	0.11 (0.19)	0.09 (0.20)	0.06 (0.07)	0.05 (0.07)
Parent employment (missing)	0.30 (0.69)	0.35 (0.69)	−0.21 (0.25)	−0.18 (0.25)
Parent: religion is important	0.51 (0.33)	0.54 (0.33)	0.21 (0.12)	0.23 (0.12)
Parent: religion is important (missing)	0.22 (1.55)	0.10 (1.56)	0.51 (0.53)	0.50 (0.54)
Parental health status	−0.41 (0.27)	−0.32 (0.27)	−0.20* (0.09)	−0.18 (0.09)
Parental health status (missing)	−0.59 (1.83)	−0.53 (1.83)	−0.13 (0.72)	−0.20 (0.73)
Household smoker	0.47* (0.19)	0.46* (0.19)	0.05 (0.06)	0.05 (0.07)
Household smoker (missing)	−0.63 (1.81)	−1.08 (1.83)	−0.66 (0.73)	−0.77 (0.74)
Married	−0.05 (0.23)	−0.07 (0.23)	0.02 (0.08)	0.01 (0.08)
Marital status missing	−0.49 (1.92)	−0.23 (1.92)	0.67 (0.67)	0.77 (0.69)
Allowed to make own decisions about what to eat	−0.02 (0.21)	−0.02 (0.21)	−0.07 (0.07)	−0.06 (0.07)
Allowed to make own decisions about what to eat (missing)	−5.68** (1.75)	−5.90** (1.76)	−2.04** (0.67)	−2.28** (0.69)
Days at least one parent was in the room while eating dinner	0.09** (0.03)	0.08* (0.03)	0.02 (0.01)	0.02 (0.01)
Days at least one parent was in the room while eating dinner (missing)	5.03** (1.72)	4.97** (1.72)	1.78** (0.65)	1.87** (0.66)
Live in neighborhood because of schools	0.03 (0.18)	−0.01 (0.18)	0.03 (0.06)	0.03 (0.06)
Live in neighborhood because of schools (missing)	0.45 (0.61)	0.45 (0.61)	0.23 (0.20)	0.24 (0.21)
Constant	12.18** (1.88)	8.52** (2.65)	0.69 (0.62)	0.35 (0.65)
School fixed effects	Yes	Yes	Yes	Yes
Observations	2800	2800	2797	2797
R-squared	0.19	0.17		
F-statistic (first stage)		18.65**		14.30**
Overidentification test (*p*-value)		0.84		0.33

Notes: Estimates from the Saturation sample of Wave I of Add Health. Instrumental variable (IV) estimates instrument for peer weight using mean friends' birth weight, the proportion of friends' parents who are obese (both biological mother and father), and the proportion of friends' parents' self-reported health status. Standard errors are in parentheses.

* Indicates statistical significance at 5%.

** Indicates significance at 1%.

Table 3
The effect of friends' weight on adolescent weight by gender

	Dependent variable			
	BMI		Probability of overweight	
	OLS (marginal effect (std. error))	IV (marginal effect (std. error))	Probit (coefficient (std. error) [marginal effect])	IV-Probit (coefficient (std. error) [marginal effect])
Whole sample (*N* = 2800)	0.30** (.03)	0.52** (0.11)	0.65** (0.08) [0.21]	1.54** (0.43) [0.39]
Males (*N* = 1440)	0.26** (.04)	0.54** (.14)	0.45** (.11) [0.15]	0.72 (.46) [0.20]
Females (*N* = 1360)	0.33** (.04)	0.56** (.17)	0.89** (.13) [0.25]	2.68** (.71) [0.53]

Notes: Estimates from the Saturation sample of Wave I of Add Health. Each coefficient is from the mean BMI (proportion overweight) among friends from a separate regression. All regressions control for the same variables as in Table 2.
** Indicates significance at 1%.

by 0.66 units at the 75th percentile, by 0.39 units at the median, and by 0.20 units at the 25th percentile. The same pattern appears among males and females when analyzed separately. It is possible that this is the result of homophily (i.e., selection) being higher at the high end of the BMI distribution than in the middle. However, the same pattern appears for females when the grade level is used as the peer group (see below).

4.4. Influence of grade-level peers' weight

Friends are an endogenously determined peer group. As an alternative to instrumental variables and its required identifying assumptions, we conduct separate analysis defining peer groups as all students in the same grade within the same school using the Saturation sample. This definition of peers does not suffer from the same problems with endogeneity but also likely represents a conceptually different peer effect. The results for BMI are very similar to the OLS results using friends as the peer group in the Saturation sample, with the exception that peer weight is insignificant for males (Table 5). When mean BMI in the same grade within the same school is one unit higher, an adolescent's BMI is higher by 0.23 units. However, the proportion of the same grade that is overweight is not correlated with an adolescent's probability of being overweight.

With peers defined as students in the same grade, the influence of peers is relatively stable across the BMI distribution in the overall sample (*N* = 3554), but the coefficient on mean peer BMI is only statistically significant at the 25th and 50th percentiles. There is no pattern among males, but among females, the impact of mean peer BMI is nearly twice as large at the 75th percentile as at the 25th percentile (0.46 vs. 0.25).

4.5. Gender differences in peer effects?

In results not reported, we also test whether peers of the same gender were more influential in determining adolescent weight. In another set of OLS and probit analyses conducted by gender, we enter male and female grade-level peers separately using the Saturation sample. The peer effect estimates for the opposite sex were slightly smaller than for the overall grade and followed the same significance patterns. The peer effects for the same sex were not statistically different from zero. In all models, we fail to reject the null hypothesis that the coefficients for male and female peers are equal. Thus, there is no evidence that peers of the same gender have more influence than peers of the other gender.

4.6. Higher moments of the distribution of peer-group BMI

Following Clark and Loheac (2007), we ran additional OLS specifications for grade-level peer effects that included measures of the dispersion of BMI at the grade level. The first set of regressions included the coefficient of variation for BMI (i.e., the standard deviation of grade BMI divided by the mean of grade BMI) and the second set of regressions included the gini coefficient. As with the grade-level mean BMI, all statistics are calculated dropping the adolescent's own BMI. Conditional on mean BMI in the grade, higher variation as measured by the coefficient of variation is associated with lower adolescent weight; conversely, the less variation there is in BMI at the grade level, the heavier an adolescent. A 10 percentage point decrease in the coefficient of variation increases adolescent BMI by 1.3 units (standard error = 0.37). The results for the gini coefficient indicate that adolescents in grades in which BMI is more equally distributed have higher BMI; a 10 percentage point decrease in the gini coefficient increases adolescent BMI by 2.2 units (standard error = 0.73). Together these results indicate that more homogenous distributions of peer BMI are associated with higher levels of adolescent BMI.

4.7. Sensitivity tests

We also ran the same specifications using friends as the peer group in the In-Home sample. The In-Home sample is larger, but data for fewer friends per adolescent are able to be matched due to the random sampling design (Table 1). Similarly to the Saturation sample, peers' weight is positively and statistically significantly related to adolescent weight, even in

Table 4
Quantile regression of the effect of friends' BMI on adolescent BMI

	No IV			IV		
	25th percentile (marginal effect (std. error))	50th percentile (marginal effect (std. error))	75th percentile (marginal effect (std. error))	25th percentile (marginal effect (std. error))	50th percentile (marginal effect (std. error))	75th percentile (marginal effect (std. error))
Whole sample (N = 2800)	0.16** (.03)	0.28** (.04)	0.41** (.05)	0.19 (.13)	0.38* (.15)	0.66** (.20)
Males (N = 1440)	0.11* (.05)	0.21** (.05)	0.35** (.09)	0.21 (.15)	0.37* (.18)	0.54* (.25)
Females (N = 1360)	0.20** (.05)	0.32** (.05)	0.43** (.06)	0.16 (.20)	0.44* (.21)	0.85** (.26)

Notes: Estimates from the Saturation sample of Wave I of Add Health. Each coefficient is from the mean BMI among friends from a separate quantile regression. All regressions control for the same variables as in Table 2; the instruments are the same as in Table 2.

* Indicates statistical significance at 5%.

** Indicates significance at 1%.

Table 5
Alternative definitions of peer groups: marginal effect of peer weight

Definition of peers	Dependent variable	
	BMI (marginal effect (std. error))	Probability of overweight (coefficient (std. error) [marginal effect])
Friends in In-Home sample		
Whole sample (N = 6451)	0.27** (.06)	0.51* (.25) [0.13]
Males (N = 3207)	0.25* (.10)	0.41 (.39) [0.12]
Females (N = 3244)	0.29** (.08)	0.81* (.35) [0.17]
Grade-level peers in Saturation sample		
Whole sample (N = 3554)		
Mean	0.23* (.10)	−0.44 (.38) [−0.14]
25th percentile	0.20* (0.08)	–
50th percentile	0.20† (.12)	–
75th percentile	0.28 (.19)	–
Males (N = 1826)		
Mean	0.14 (.15)	−0.56 (.53) [−0.19]
25th percentile	0.20* (0.10)	–
50th percentile	0.02 (0.16)	–
75th percentile	0.09 (0.28)	–
Females (N = 1728)		
Mean	0.32* (.15)	−0.33 (.55) [−0.10]
25th percentile	0.25* (.12)	–
50th percentile	0.25† (.13)	–
75th percentile	0.46* (.23)	–

Notes: Estimates from Wave I of Add Health. Each coefficient is from the mean BMI (proportion overweight) among peers from a separate regression. Marginal effects from instrumental variables (IV) regression and IV-probit for In-Home sample. Marginal effects from OLS and quantile regression for grade-level peers. All regressions control for the same variables as in Table 2; the instruments are the same as in Table 2.

† Indicates statistical significance at 10%.

* Indicates statistical significance at 5%.

** Indicates significance at 1%.

specifications that control for the endogeneity of peer groups (except for overweight status among males; Table 5). However, the magnitude of the marginal effect of mean peer BMI and overweight status is smaller in the In-Home sample than in the Saturation sample. There also appear to be smaller differences between genders in the influence of peer measures.

We also ran double-log models of BMI using grade-level peers, the results of which can be interpreted as elasticities. The elasticity of adolescent BMI with respect to changes in mean grade-level BMI for the whole sample was 0.28 (i.e., a 10% increase in mean grade BMI is associated with a 2.8% increase in adolescent BMI). In the whole Saturation sample, there was no distinct pattern across percentiles: 25th = 0.28, 50th = 0.20, and 75th = 0.25. Similarly to the results in Table 5 in levels of BMI, the elasticities for males were generally insignificant. The trend for increased influence of peers at higher levels of BMI remained for females: 25th = 0.30, 50th = 0.31, and 75th = 0.48. Models of log BMI as a function of mean peer BMI in levels reveal that, in percentage terms, females exhibit larger increases in BMI with each 1-unit increase in mean grade-level BMI: 25th = 1.3%, 50th = 1.3%, and 75th = 2.2%.

In the grade-level analysis, our peer effect coefficient could be biased by pre-existing trends in BMI within a school that create an effect of grade on BMI. In the raw data, after adjusting for age and sex, only one of the 16 schools in the Saturation sample had a significant trend in BMI by grade. The grade-level results are robust to the elimination of that school from the estimation sample (N = 147 dropped). For example, OLS estimates for the whole sample, males and females are: 0.26 (0.10), 0.13 (0.15), and 0.42 (0.15). Thus, we do not see strong evidence of pre-existing trends in grade-level BMI within schools.

5. Discussion

This study is the first to estimate peer effects for adolescent weight. The data allow us to construct a definition of peer groups using nominated friends within schools, which captures a potentially more influential group of peers than previous definitions at the school level. Endogenous selection into peer groups is controlled for using a combination of school fixed effects, instrumental variables analysis, and alternative definitions of peers (i.e., grade-level peers).

Mean peer BMI is correlated with adolescent BMI and the proportion of peers that are overweight is correlated with the probability of an adolescent being overweight, even after controlling for endogenous peer groups. There is also evidence that females are more sensitive to peer BMI and overweight status than males. In addition, peer weight is more influential among adolescents with the highest BMI.

These facts can help explain the dramatic rise in overweight among adolescents in the past few decades. The results are consistent with social dynamics in which weight gain ripples through peer networks and feeds back on itself. The fact that it is adolescents with the highest BMI that are most influenced by peers can also help to explain the especially dramatic increases in the right tail of the BMI distribution. Importantly, the results are also consistent with mechanisms in which decreases in overweight spread through peer networks. The results are consistent with, or suggest the existence of, social multipliers for adolescent overweight policies.

The language of "consistent with" is important as the analysis in this study is cross-sectional. We have shown that, controlling for selection, there is a cross-sectional correlation between adolescent BMI and peer-group BMI. Longitudinal analysis would be required to determine if friends' BMI or overweight status leads to *changes* in BMI and overweight prevalence among adolescents. Later waves of Add Health could provide such information as long as issues of sample attrition and changing peer groups (i.e., de-selection) are taken into account. Longitudinal analysis for adults in the Framingham Heart Study indicates that obesity may spread through social ties (Christakis and Fowler, 2007). However, no study has yet shown that the relationship between peer-group weight and individual weight change is symmetric (i.e., weight loss also spreads through social networks), a crucial determinant of the relevance of social multipliers for the effectiveness of interventions targeted to reduce obesity.

Despite the advantage of being able to identify peer groups at the level of friends, the data and our definitions of peer effects have some limitations. First, the data represent a fairly limited sample of students in 16 schools. Second, our use of reported friends leaves many incomplete social networks. Nominated friends outside of school and romantic partners are not captured.[14] There are also more sophisticated definitions of social networks that account for mutual friendships, friends of friends, and more (e.g., Bearman and Moody, 2004; Bearman et al., 2004). For instance, Christakis and Fowler (2007) found that the direction of friendship made a difference; mutual friends exhibited much larger influence on each other's weight than did uni-directional friendship nominations as used in this study.

As with any instrumental variable analysis, the validity and strength of the instruments is important. OLS estimates of peer effects in this context are expected to be upwardly biased as adolescents likely choose friends that are similar to themselves. However, the instrumental variable estimates are larger in magnitude than the OLS and probit estimates, possibly indicating that the instruments are weak or fail to meet the exclusion restriction. As reported above, the *F*-statistics from the first stage are large and significant. Another explanation for the larger instrumental variable estimates is classical errors in variables for mean peer weight, which would lead to attenuation bias in the OLS estimates but not in the IV estimates. The measurement error could result from the fact that the peer measure does not capture all friends (i.e., listed friends that can be matched are a subset of the actual peer group), the weight variables can be missing even for those friends that are matched (e.g., three of five listed friends have BMI data), and misreporting of BMI among friends with available data. Despite these issues, mean BMI among peers is still significantly correlated with adolescent BMI using students in the same grade as the peer group, an exogenously determined peer-group within schools.

Future research is needed to better understand the mechanisms behind the influence of peers on weight. Several candidates exist, such as peer influence on weight loss attempts, physical activity, and perceptions of weight. The causal mechanisms should also be consistent with effects of higher moment of the BMI distribution. Knowledge about the source of peer influence on weight and the size of any social multipliers will improve implementation and evaluation of policies aimed at reducing adolescent overweight.

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[14] Separate identification of friends also listed as romantic partners was possible in the data used by Bearman and coauthors (Bearman and Moody, 2004; Bearman et al., 2004), but not in the data covered under our data use agreement.

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