Adolescent Friendships, BMI, and Physical Activity: Untangling Selection and Influence through Longitudinal Social Network Analysis

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Abstract

Bioecological theory suggests that adolescents' health is a result of selection and socialization processes occurring between adolescents and their microsettings. This study examines the association between adolescents' friends and health using a social network model and data from the National Longitudinal Study of Adolescent Health (N = 1,896, mean age = 15.97 years). Results indicated evidence of friend influence on BMI and physical activity. Friendships were more likely among adolescents who engaged in greater physical activity and who were similar to one another in BMI and physical activity. These effects emerged after controlling for alternative friend selection factors, such as endogenous social network processes and propinquity through courses and activities. Some selection effects were moderated by gender, popularity, and reciprocity.

Keywords: Adolescence, Friendships, Obesity, Physical Activity, Social Networks

Adolescent Friendships, BMI, and Physical Activity: Untangling Selection and Influence through Longitudinal Social Network Analysis

Adolescent obesity and physical activity levels are rising public health concerns around the world (Spruijt-Metz, 2011). Over the last 30 years in the U.S., the rate of adolescent obesity has nearly tripled and only around one third of high school students meet the recommended level of physical activity (Child Trends, 2010). Adolescents who are overweight tend to be physically inactive, and are more likely to experience chronic physical health problems, lower economic success, and negative psychological outcomes compared to their peers (e.g., Puhl & Latner, 2007). In light of these trends, U.S. government agencies and social science researchers have urged for a stronger consideration of how the social context influences adolescents' physical health (Harrison et al., 2011; U.S. Department of Health and Human Services, n.d.).

Friendships are an important component of adolescent health (e.g., Duncan, Duncan, Strycker, & Chaumeton, 2007). According to bioecological theory, adolescent development is driven by the bidirectional processes of selecting microsettings and the influence of those microsettings on adolescents (Bronfenbrenner & Morris, 2006). Indeed, selection and influence comprise the backbone of theories explaining peer homophily (Kandel, 1978). When applied to adolescents' health, these theories assert that adolescents' friendships develop based on adolescents' attributes, their health, and endogenous social network processes. In return, adolescent health is affected by individual-level processes and friends' health. Prior research with adults has found social influence on BMI (Christakis & Fowler, 2007). However, these findings have been criticized for not considering that individuals may preferentially associate with others who are similar to themselves (Lyons, 2011). Researchers must simultaneously examine selection, influence, and other friendship factors (e.g., homophily on demographic characteristics and propinquity through courses and extracurricular activities) in order to isolate the likely underlying processes. The only published study that explicitly modeled selection and influence on adolescents' BMI found evidence of selection related to BMI, but not friend influence (de la Haye, Robins, Mohr, & Wilson, 2011a). Given the importance of this topic, further research is needed to clarify the association between adolescents' health and friendships. A more complete understanding of health and friendship dynamics can inform theories of adolescent development and have implications for public health efforts.

The goal of the current study is to examine the complex interconnections among individual health indicators—namely BMI and physical activity—and friendship groups as noted in bioecological and homophily theories. We focus on BMI and physical activity in conjunction because the two are causally intertwined, yet have not been studied together within a dynamic network framework. By simultaneously analyzing BMI and physical activity, we can overcome potential confounds and assess whether their relations to friendship processes persist net of one another and whether friend influence on physical activity accounts for friend influence on BMI. We extend prior work by (1) focusing on the dynamics of friendship networks, BMI, and physical activity in conjunction, (2) examining U.S. adolescents in two quite different high school settings, and (3) testing several moderators of friend selection and influence. One statistical approach that can simultaneously capture these multi-level processes as they unfold longitudinally is social network analysis (Veenstra & Dijkstra, 2011). Specifically, the stochastic actor-based (SAB) model allows us to jointly test selection and influence related to BMI and physical activity (Snijders, 2001; Snijders, van de Bunt, & Steglich, 2010). A strength of the SAB model is that it can control for multiple factors that affect friend selection, including homophily on individual attributes (e.g., gender), propinquity through settings within schools, and network processes (e.g., triadic closure).

Empirical Evidence on Friendships, BMI, and Physical Activity

Adolescent friends tend to be similar in terms of their BMI (e.g., Trogdon, Nonnemaker, & Pais, 2008; Valente, Fujimoto, Chou, & Spruijt-Metz, 2009), general level of physical activity (Duncan et al., 2007; King, Tergerson, & Wilson, 2008), and organized sport participation (de la Haye, Robins, Mohr, & Wilson, 2010). Such homophily may arise through selection if adolescents prefer friends like themselves or if adolescents who are not athletic or with a high BMI are socially excluded and turn to one another for friendship (Schaefer, Kornienko, & Fox, 2011). By contrast, socialization theories suggest that friends become more similar in terms of their health over time due to shared activities, modeling of habits, or shared norms (Harrison et al., 2011).

To date, the existing evidence more strongly supports the role of selection. For instance, new friendships are more likely to develop among adolescents with a similar BMI and overweight peers are less likely than non-overweight peers to be selected as friends (Crosnoe, Frank, & Mueller, 2008). In addition, co-participation in organized athletic activities promotes the maintenance and formation of friendships over time (Schaefer, Simpkins, Vest, & Price, 2011). Popularity is also associated with physical activity (Ommundsen, Gundersen, & Mjaavatn, 2010) and being an athlete in a jock crowd (Brown & Larson, 2009). In the only published studies testing both selection and influence simultaneously, researchers found that adolescents selected friends who were similar to themselves in BMI and physical activity (de la Haye et al., 2011a, 2011b). Although friends did not become more similar in terms of their BMI over time (de la Haye et al., 2011a), best friends became more similar in their physical activity over one school year (de la Haye et al., 2011b).

Prior research has found clear associations between friends and adolescents' health. However, the findings considering both friend selection and influence are limited to Australian middle school students (de la Haye et al., 2011a, 2011b). A strength of the current study is that we test the dynamics of friendship, BMI, and physical activity simultaneously and in a sample of U.S. high school students. In addition, inclusion of BMI and physical activity afforded the opportunity to test whether friend influence on physical activity might help explain the possible contagion on BMI. Because physical activity is an immediate precursor of BMI (Spruijt-Metz, 2011), one of the ways friends may influence adolescents' BMI is by changing their level of physical activity.

Scholars have theorized that the processes of friend selection and influence may not be uniform across adolescents. Specifically, the selection and influence of friends may depend on individual attributes, friends' popularity, and whether the friendship was reciprocated (for an overview, see Brechwald & Prinstein, 2011; Brown, Bakken, Ameringer, & Mahon, 2008; Brown & Larson, 2009). To test this, we first examined adolescents' individual attributes. Age, race, gender, socioeconomic status, and self-esteem are important in understanding adolescents' orientation toward peers and are associated with weight stigmas, ideal body image, and weight maintenance behaviors (e.g., Crosnoe et al., 2008; Rancourt & Prinstein, 2010). For example, certain adolescents may be less susceptible to peer influence on health (e.g., adolescents with high self-esteem and older adolescents; Botvin, Epstein, Schinke, & Diaz 1994), whereas, selection and influence on BMI and physical activity may be heightened for groups where thin ideal body images are more pronounced (e.g., females, European Americans; Barroso, Peters, Johnson, Kelder, & Jefferson, 2010; Crosnoe et al., 2008). Second, scholars have asserted that popular peers are more influential and receive more bids of friendship than less popular peers

(Cohen & Prinstein, 2006). Popularity may further affect friend selection, for instance by offsetting the negative stigma otherwise associated with poor health. Third, scholars have asserted that friendship reciprocity alters the strength of friend influence, although there is disagreement about the direction of this effect (e.g., Urberg, Cheng, & Shyu, 2006). Moreover, the capacity to form close, reciprocated friendships may vary based upon health factors (Haas, Schaefer, & Kornienko, 2010). Because the evidence is just emerging on many of these relations, we explored if friend selection and influence were moderated by adolescents' characteristics, friends' popularity, and friendship reciprocity.

Research Questions

This study tested five sets of research questions. First, we expected that adolescents would be less likely to select friends who are overweight or have lower physical activity. Second, we expected that adolescents would select friends with similar BMI and physical activity. Third, we expected that friends' BMI and physical activity would predict adolescents' subsequent BMI and physical activity (i.e., friend influence). Fourth, we expected that friend influence on physical activity may account for the influence of friends' BMI on adolescents' BMI. Fifth, we explored whether friend selection and influence varied across adolescents and relationships.

Method

Participants

The current investigation is based on students in the two largest high schools with longitudinal data in the National Longitudinal Study of Adolescent Health (Add Health). The two schools in our sample represent different types of public high schools (Table 1). The most notable difference between schools was that School A was predominantly White, whereas

School B was more racially and ethnically diverse. As shown in Table 1, the sample (N = 1,896) was about equally divided on gender, 15.97 years of age on average, and in grades 9-11.

Only a subset of schools in the Add Health study could be included in the current investigation. First, by design, longitudinal data were only collected from all students at 16 of the 132 schools (which are known as the saturated schools). Our model requires longitudinal data on the complete network within a school in order to differentiate friend selection from influence. Of the 16 saturated schools, 14 were eliminated for a variety of reasons: (a) six middle schools had high rates of attrition, (b) three schools had response rates lower than 75%, and (c) five schools had high rates of missing friendship data for the Wave I in-home interview (i.e., ~40% of respondents could only nominate one male and one female friend due to a computer error). Though the SAB model can accommodate missing data, high rates of nonresponse and missingness are likely to result in biased parameter estimates (Huisman & Steglich, 2008). Within the two remaining schools, adolescents who were 12th graders in Wave 1 were dropped because too few of them had longitudinal data (N=657).

Measures

Because Add Health includes both students and their friends, it provides self-report data on all measures of interest. The data in this study came from three adolescent questionnaires and a parent questionnaire. The first adolescent questionnaire administered at school during Wave 1 included adolescents' activity participation and demographic characteristics. Approximately one to eight months later, adolescents provided the second portion of the Wave 1 measures during an in-home interview (which we label Time 1). Approximately one year after the Wave 1 in-home questionnaire, another adolescent questionnaire was administered at home during Wave 2 (which we label Time 2). The in-home interviews provided adolescents' weight, height, physical activity, and friendships. Parents reported demographic information in their questionnaire at Wave 1.

BMI. Using self-report measures of height and weight, we computed adolescents' BMI percentile using the Center for Disease Control's (CDC) calculators to compute BMI percentile specific to each adolescent's age and gender (Kuczmarski et al., 2000). The raw BMI scores in our sample ranged from 11.75-51.37. We categorized youth into one of the four CDC weight status categories based on their BMI percentile: underweight (<5th percentile), healthy weight (5th percentile to < 85th percentile), overweight (85th percentile to < 95th percentile), and obese (≥ 95th percentile).

Physical activity (PA). Adolescents reported the number of times during the past week they participated in three types of physical activities: (a)"an active sport, such as baseball, softball, basketball, soccer, swimming, or football," (b) "roller-blading, roller-skating, skate-boarding, or bicycling," and (c) "exercise, such as jogging, walking, karate, jumping rope, gymnastics or dancing" (0 = *not at all*, 1= *1 or 2 times*, 2 = *3 or 4 times*, 3= *5 or more times*). These items were summed to create a variable that ranged from 0 to 9.

Friendship network. Adolescents identified their 5 closest female and 5 closest male friends (up to 10 friends total). Students were allowed to nominate any students in their school, not just those in the same classroom or grade. Nominations of out-of-school friends were not considered because we did not have data on such friends.

The only extreme case on friend nominations occurred in school B and was due to what we believe was a computer error with Add Health. This particular case had an unreasonably high number of friendship nominations and was often nominated multiple times by the same respondent. To address this, we converted all outgoing nominations to missing for anyone who nominated the problematic case multiple times. There were approximately 40 adolescents in school B whose outgoing friendship ties were converted to missing.

Control variables. Obtaining unbiased estimates of the associations among friendships and adolescents' health requires controlling for other potential predictors (Steglich, Snijders, & Pearson, 2010; Veenstra & Steglich, 2011). We controlled for several demographic and behavioral factors that predict BMI, PA, and friendships, including age, race, gender, self-esteem, breakfast, and parent indicators (e.g., Harrison et al., 2011). Adolescents' self-esteem was the average of six self-reported items (e.g., "I have a lot of good qualities," and "I like myself just the way I am"; 1 = *strongly agree*, 6 = *strongly disagree*; alpha = .83). A dichotomous indicator of whether adolescents usually ate breakfast was created based on adolescents' report of eating several breakfast items (i.e., milk, coffee or tea, cereal, fruit or juice, eggs, meat, snack foods, bread or toast or rolls, and other item; 1= one or more items, 0=no items). Mothers reported on their education level (0= *less than high school* to 3= *college degree or beyond*) and family income. A dichotomous measure of parental physical activity engagement was created based on one-item assessing whether adolescents had engaged in a sport activity with either parent in the last four weeks. A dichotomous indicator of parents' obesity was created based on whether mothers stated that either the adolescents' biological mother or father was obese (1 = *yes*, 0 = *no*). All individual-level attributes were centered using the school mean prior to estimation.

We also controlled for propinquity among adolescents within the school by including indicators of course overlap and participation in the same school-based extracurricular activities. Supplemental data from the Adolescent Health and Academic Achievement Study was used to create an indicator of the number of courses each dyad took together during the school year (range = 0-14). Sports included 12 activities (e.g., football, volleyball) and non-sport activities included 18 activities (e.g., book club, student council). We computed (a) the number of adolescents' sport and non-sport activities, and (b) a dyadic indicator of sport co-participation and non-sport co-participation (1= both participated in at least one of the same activities, 0 = no co-participation). To test whether we over-controlled for selection on physical activity by including activity co-participation, we estimated models that excluded the selection effects related to activity participation and course overlap. The physical activity results did not substantively differ from those reported in the full model.

Missing Data. Missing data existed in the form of item-nonresponse (i.e., a student who skipped an item on the survey they completed) and participant-nonresponse due to attrition (i.e., a student who did not participate at one time point). Data missing due to item-nonresponse was imputed by the SIENA software using the mean (Ripley, Snijders, & Preciado, 2011). For participant-nonresponse we followed the recommendation of Huisman and Steglich (2008) and retained all participants observed during at least one of the time points. For adolescents who still attended the school at Time 2 but did not complete a Time 2 survey, we coded all of their outgoing ties as missing. For adolescents who no longer attended the school at Time 2, we used structural zeros to code their outgoing and incoming ties within that school as impossible.

Analysis Plan

We used a stochastic actor based (SAB) model—often referred to as a SIENA model (Snijders 2001; Snijders, van de Bunt, & Steglich, 2010). The SAB model simultaneously estimates changes in the network and changes in individual BMI and PA (for an overview, see Snijders et al, 2010; Veenstra, Dijkstra, Steglich, & Van Zalk, 2013; Veenstra & Steglich, 2012). We estimated a SAB model for each school and present results separately.

The SAB model uses a network function to predict whether existing ties are likely to persist over time (versus dissolve) and if new ties are likely to form. This function includes three types of effects that predict the likelihood of a friendship between two adolescents over time (see Ripley et al, 2011 for effect specification). First, the model estimates whether adolescents with certain attributes are more likely to send friend nominations (ego effects) or receive friend nominations (alter effects). Ego and alter effects were included for BMI, PA, grade, gender, mothers' education, participation in sport activities, and participation in non-sport activities. Second, to capture tendencies toward homophily, the model included similarity effects for BMI, PA, grade, gender, and mothers' education. For the categorical variable race, we used the "same" effect, which indicated whether dyad members were the same race or not. We included dyadic covariates for sport activity, non-sport activity, and course overlap. Third, the network function controls for endogenous network processes by which the network itself promotes some friendships over others. These effects included reciprocity, transitive triplets, and popularity. Reciprocity captures the likelihood that adolescents will select friends who have previously selected them. Transitive triplets capture the likelihood of adolescents selecting friends whom a current friend has previously selected. The popularity effect estimates how an adolescent's number of incoming nominations predicts the likelihood of receiving future nominations. For each adolescent, popularity is measured as the square root of the number of incoming nominations, which gives greater weight to differences in popularity among less popular adolescents (e.g., one additional friend increases popularity more for adolescents with few friends versus adolescents with many friends).

The model included two behavior functions, one to model change in BMI and one to model change in PA. These functions not only predict change in health, but also capture adolescents' tendencies to remain at particular levels of each health indicator. Friend influence was measured using the total similarity effect, which captures whether adolescents were likely to adopt levels of BMI and PA that resemble their friends, weighted by the number of friends. We also controlled for several individual attributes that may affect each health outcome (see Table 2a for the specific indicators).

Testing if Physical Activity Accounts for Influence on BMI

Two models were required to test whether contagion on BMI was a product of friend influence on physical activity. The first model was the full model described above. Second, we estimated a reduced version of the full model that omitted the effects of physical activity on BMI and friend influence on physical activity. We compared the coefficient for friend influence on BMI across the two models. If friend influence on physical activity explained friend influence on BMI then the coefficient for friend influence on BMI should decrease from the reduced to the full model.

Testing Moderation

To test moderation of friend influence, we examined the following interaction effects for BMI and PA: total similarity by (a) ego's age, (b) ego's race (dummy codes for Hispanic, African-American, Asian, and other), (c) ego's gender, (d) ego's mother's education, (e) ego's self-esteem, (f), alter's popularity, and (g) reciprocity. Interactions involving individual attributes were calculated by multiplying the total similarity effect by the moderator. For popularity, influence from each alter was weighted by the alter's number of incoming nominations when calculating total similarity (Ripley et al., 2011). For the reciprocity interaction, total similarity was calculated using only reciprocated friendships. Separate models were estimated for each of the seven moderators. In total, 24 interactions were tested across both schools, plus 16 interactions with race in School B.

We also tested whether these same potential moderators affected selection based on BMI and PA. First, the moderating effect of the five individual attributes was tested by creating interaction terms between each attribute and health indicator. For every pairing, nine interactions were created. For example, the three BMI selection effects (i.e., ego, alter, similarity) were interacted with the three gender selection effects resulting in nine interactions. Seventy-two such interaction effects were tested in each school to examine gender, grade, maternal education, and self-esteem. In addition, 72 interactions for race were tested in School B. Second, we interacted popularity with each BMI and PA selection effect (six interactions). Third, we interacted reciprocity with (a) similarity on each health factor and (b) individual BMI and PA (four interactions). In the interactions with reciprocity, we did not specify separate ego and alter effects for health indicators because egos and alters are indistinguishable in reciprocated friendships. In total, 236 interactions for selection were tested. Because there were far more interaction effects for selection than for influence, we employed a three-stage procedure. We first estimated the full model and tested each interaction using a score test (Ripley et al., 2011). This allowed us to evaluate the extent to which the exclusion of each interaction from the model reduced model fit. Then, for moderators that were consistently significant (i.e., across multiple interactions), we added the interactions and re-estimated the model. For this second step, we tested each moderator separately. Third, we estimated a final model for each school that only included interactions found to be significant in step two.

Results

Predicting BMI and PA

We now explicate the results for the behavior functions for BMI and PA (Table 2a). The results revealed significant and positive effects for total similarity on BMI and PA in both schools. These results suggest that adolescents adopted levels of BMI and PA that were similar to their friends' BMI and PA (respectively) over time. However, we did not find evidence that influence on BMI was partially explained by influence on PA. Coefficients for BMI total similarity from the reduced model were significant in both schools ($p < .05$), but differed only slightly from the full model (School A: $b_{Reduced} = 3.32$, $b_{Full} = 3.31$; School B: $b_{Reduced} = 1.60$, $b_{Full} = 1.69$).

We also examined whether influence on BMI and PA varied based on individual attributes, popularity, and reciprocity. None of these interactions were statistically significant. The lack of significant results suggests that the friend influence effects observed in both schools for BMI and PA did not vary in strength based upon these factors. The results are available from the authors.

Predicting Friendship Ties

Turning to the friend selection function, we observed significant positive effects for reciprocity, transitive triplets, and popularity as expected (Table 2b). In addition, we found that several individual attributes and indicators of propinquity were related to friend selection. Of note, we observed homophilous selection on grade and gender in both schools, mothers' education in School A, and race in School B. Adolescents in higher grades were more likely to be selected as friends (grade alter). In combination, these results suggest that both homophily and grade-driven popularity drove friend selection. Adolescents largely chose friends within their own grade; but, when selecting friends outside their grade, adolescents were more likely to reach up, to higher grades, than to reach down. In addition, in both schools, the positive mothers' education alter effects indicated adolescents with more educated mothers were more attractive as friends. Overlaps in coursework and extracurricular activities were significant predictors of friend selection in both schools. School A displayed fewer incoming ties among sport participants (sport alter), which is suggestive that sports participation was negatively associated with popularity.

In terms of health indicators, we found that similarity on BMI and PA was significant and positive in both schools, indicating tendencies to select friends who were similar in these aspects. The PA ego and alter effects were significant and positive in both schools, suggesting that more physically active adolescents selected more friends and were selected more often as friends. And, the positive BMI ego effect in School A indicates that higher BMI adolescents selected more friends than lower BMI adolescents. Notably, we did not observe the expected negative effects of BMI alter.

We also tested whether BMI and PA selection effects were moderated by individual attributes (i.e., age, race, gender, SES, and self-esteem), popularity, and reciprocity. Of the seven moderators tested, three had multiple significant score tests across both schools: gender (33% of the tests were significant), popularity (83% significant), and reciprocity (75% significant). Fewer than 20% of the score tests were significant for the other moderators. Thus, we further examined the moderation effects for gender, popularity, and reciprocity. We estimated twelve separate models, each adding the interactions between one moderator and either BMI or PA that had a significant score test. Interactions that were significant in these models were included together in the final, full model, reported in Table 2b.

Beginning with gender, we observed significant moderating effects only in School A. Interactions between gender similarity and BMI alter, as well as gender alter and BMI similarity were positive. These effects suggest that adolescents with higher BMIs were more likely to be selected as friends within same-sex friendships than cross-sex friendships, and homophily on BMI was stronger when selecting female friends than male friends. Turning to PA, the only significant interaction with gender was also in School A. The positive interaction between female similarity and PA similarity indicates that similarity on PA was more likely in same-sex versus cross-sex friendships.

The interactions involving popularity were significant in both schools for selection effects related to PA. These interactions must be evaluated in light of the main effects of PA and popularity, which were all positive in both schools. The interactions, which are all negative, indicate that the effects of PA and popularity were not additive—the negative interactions offset the positive main effects of popularity and PA on friendship likelihood. All of the interactions suggest that selection based on PA was less important when friends were popular than when friends were less popular.

The last set of interactions tested how reciprocity moderated friend selection. We only observed significant moderating effects of reciprocity on BMI effects. Beginning with School A, we observed a negative interaction between reciprocity and BMI similarity. In combination with the positive main effects for reciprocity and BMI similarity, this indicates that these effects were not additive. Rather, BMI similarity was stronger among unreciprocated dyads than reciprocated ones. In other words, being similar in terms of BMI was more important for unreciprocated friendships than reciprocated ones. In School B, we found a significant positive interaction between reciprocity and ego BMI. This effect suggests that reciprocated friendships were more likely for adolescents with higher, versus lower, BMI.

Discussion

Developmental theories assert that adolescents' friendships and health influence one another over time (Bronfenbrenner & Morris, 2006; Harrison et al., 2011). Thus, to understand and address the obesity epidemic among adolescents, it is imperative to more fully understand the role of friends. Several studies have shown that friends are similar in terms of BMI and physical activity (e.g., Duncan et al., 2007; Trogdon et al., 2008). Although these studies highlight the role of friendships in adolescents' health, they provide little insight on whether these similarities emerged because of individuals' influence on microsettings (i.e., selection) or the influence of microsettings on individuals (i.e., influence). This distinction is important because of its implications for both theories of development and practical efforts to curb obesity. This study builds on previous work by using longitudinal data to simultaneously examine selection and influence. Specifically social network modeling afforded the opportunity to capture the co-evolution of friendships and individual health while controlling for several additional correlates of adolescents' BMI, physical activity, and friend selection. In addition, the SAB model allowed us to test several more distinct processes by which selection and influence can occur.

Friend Influence

The current study offers evidence of friend influence on BMI in both of the schools observed. Evidence for social influence on BMI has been found among adults in the U.S. (Christakis & Fowler, 2007) and with previous studies in youth (Trogdon et al., 2008), neither of which accounted for friend selection processes. However, evidence for influence was not found in a similar longitudinal social network analysis of Australian early adolescents (de la Haye et al., 2011a). There may be a few differences in the participants and methods contributing to the divergence in findings. Although both samples included high school students, the Australian study only included first year high school students, whereas we included students who were in their first, second, or third year of high school. There may be different friendship processes during the first year, which is a transition point, than the remaining high school years. In addition, the Australian study included actual height and weight measured at four time points across 16 months. Add Health data includes self-report of height and weight. Because there are so few longitudinal studies on these processes among adolescents, it is unclear if the divergent findings are the result of different processes, samples, or methods. Reconciling these findings through further study is needed given the serious public health consequences of these processes.

One contribution of the current paper is that we also tested friend influence on physical activity, which is one of the central predictors of obesity. Parallel to another recent longitudinal study (de la Haye et al., 2011b), our findings provide evidence of friend influence on physical activity over time in both of the observed schools. This effect held after controlling for a host of factors that predict physical activity, including adolescents' BMI, and was consistent across two different school contexts. Not only do the findings of this study add another piece of evidence to the growing consensus that friends may influence each other's physical activity over time, we also addressed a new question: Does friend influence on physical activity explain how friends influence adolescents' BMI? Our data suggest that the answer is no. This is surprising as physical activity is a central immediate precursor of BMI (Spruijt-Metz, 2011). However, it may be that changes in physical activity are not enough to change BMI. Interventions that focus on multiple precursors of obesity, such as nutrition and physical activity, have been shown to be effective (Wilfley et al., 2007). It may be necessary to integrate multiple behavioral mechanisms, such as diet and physical activity, to uncover the mechanisms through which friends influence adolescents' BMI.

Our findings that friend influence occurred on BMI and physical activity are notable because they emerged in two quite different schools, across different adolescents (e.g., girls and boys), and over the course of one year. However, two points must be emphasized. First, influence can take several forms. For instance, friend influence can lead to an increase, decrease, or no change in BMI (i.e., remaining similar to one's friends despite opportunities to change). Second, the distribution of BMI did not change over time. Thus, whereas the observed peer influence on BMI may share responsibility for maintaining the existing rates of obesity, it did not further the obesity problem. By contrast, the mean level of physical activity decreased significantly over time in both schools, which is consistent with prior research (de la Haye et al., 2011b) and might be attributable to friend influence. This pattern of results highlights the need to better understand when influence is positive (e.g., toward healthier BMI) versus negative (i.e., toward under- or overweight).

Selecting Friends

Consistent with previous research (de la Haye et al., 2011a), our findings suggest that adolescents were more likely to have a friendship with someone who was similar in weight and physical activity. Selecting friends in similar health may have positive and negative consequences for adolescents depending upon what happens within the friendship. Friendships among healthy youth could reinforce healthy behaviors, yet it may also reinforce stigmas about poor health. Friendships among obese or inactive youth could reinforce unhealthy behaviors; however, these friendships may also provide comfort, support, and reinforcement of their identity, which can otherwise enhance their development. For instance, such positive relational aspects have been found among friends who both have depressive symptoms (Baker, Milich, & Manolis, 1996).

Our tests of moderation revealed that selecting friends based on BMI and physical activity sometimes varied based on adolescents' gender, friends' popularity, and friendship reciprocity. The gender results suggested that BMI had stronger effects on friend selection for females and in same-sex dyads than their peers, but only in School A. Notably, School A is the predominantly white school with slightly higher maternal education than School B. Although we cannot test for setting effects with only two schools, this pattern is consistent with prior research. Weight stigmas and concerns as well as thin ideal body images are often more pronounced for females, Caucasians, and adolescents from higher socio-economic backgrounds than their peers (Boyington et al., 2008; Barroso, Peters, Johnson, Kelder, & Jefferson, 2010; Crosnoe et al., 2008; Hansson et al., 2009; Resnicow et al., 2000). It is possible that female Caucasian students have greater awareness or sensitivity to weight-related norms than males or students of other racial and ethnic backgrounds, which could lead to weight playing a more prominent role in friend selection for female Caucasian students.

Our test of moderation also revealed multiple interactions between popularity and physical activity in both schools. The main effects of selection based on physical activity suggest that physically active youth have more friends and are nominated by more peers than less physically active youth. This pattern is consistent with previous research suggesting that popularity is associated with physical activity (Ommundsen, Gundersen, & Mjaavatn, 2010), being an athlete in a jock crowd (Brown & Larson, 2009), and weight maintenance behaviors (Rancourt & Prinstein, 2010). The interactions suggest that physical activity was less important for friendship selection when choosing popular peers. Thus, being physically active may promote one's popularity among peers, but these effects are attenuated when befriending popular peers, who are preferred whether or not they are physically active.

Finally, we observed interactions between reciprocity and friend selection based on BMI, though the effects differed across school settings. In the primarily Caucasian school, similarity on BMI was stronger in unreciprocated dyads than reciprocated ones. It may be that similarity is more important for weaker friendships that are more often marked by non-reciprocity. In the racially diverse school, reciprocity was stronger for higher BMI adolescents. This effect suggests that higher BMI adolescents were more likely to have closer friendships, or conversely, less likely to have weaker, non-reciprocated friendships. Such an effect would be expected in settings where obesity is stigmatized, thereby pushing higher BMI adolescents to form closer, more supportive friendships than lower BMI adolescents.

Limitations and Future Directions

Although these findings suggest that friends become more similar over time in BMI and physical activity, they do not pinpoint the specific mechanisms by which this happens. Physical activity as measured in this study was not found to explain friendship similarity on BMI, but several other potential mechanisms could be further explored. Research suggests that adolescents' eating and physical activity varies based on whether they are alone or with someone else as well as the habits of their companions. For example, obese adolescents are more physically active when they are with friends compared to being alone (Salvy et al., 2009). One possibility is that engaging in activities with friends fosters enjoyment and fulfills people's need for a sense of relatedness, which promotes adolescents' motivation to prolong engagement (Ryan & Deci, 2000). Another possibility is that friends may serve as role models and set behavioral expectations for the peer group. More research is necessary to address these potential mechanisms.

There are several limitations related to the Add Health methods that are worth noting. First, most of the measures were based on adolescents' self report. Although self-reported height and weight are highly correlated with actual height and weight, it will be important to include objective measures of all indicators in future studies (de la Haye et al., 2011a; Spruijt-Metz, 2011). Second, we included several indicators that have been shown to predict adolescents' weight and physical activity, such as eating breakfast. However, this study would have been strengthened through more detailed information on health related-behaviors, such as diaries of diet and activities with parents. Third, adolescents' nominations were limited at 5 female and 5 male friends. Thus, it is possible that the current findings reflect processes among adolescents' closer or stronger friendships.

One goal of this paper was to examine selection and influence on physical activities. However, the measures of physical activities in Add Health have a few limitations. First, the items on general physical activity assessed how often adolescents said they participated in a variety of exercise activities. A stronger methodology would be the use of objective measures of physical activity, such as accelerometers, or even daily diaries. Second, measures of participation in organized physical activities (i.e., school athletic activities) were not collected at both time points. We were unable to conduct the same tests for organized activity participation that we examined for general physical activity (i.e., testing selection and influence in organized activity participation over time). Thus, we also were unable to determine if friend influence on physical activity and BMI is a product of friends' influencing one another's activity participation. Finally, measures of both informal and organized physical activity did not assess how often adolescents engaged in these activities with their friends. Research suggests that adolescents' physical activity varies based on whether they engage in these activities alone or with a companion (Salvy et al., 2009). Engaging in these activities with friends versus alone has subsequent implications for potential influence (e.g., modeling). Moreover, by spending more time together, there is greater capacity for behaviors to align through friend influence and bonds of friendship to develop. Combining a network methodology with more fine-scale data, such as through ecological momentary assessment, may be a useful avenue.

In this study, we examined whether adolescents were likely to modify their behavior in the direction of their more popular friends. Brown and Larson (2009) assert that there are two types of popularity: (a) one based on status and (b) one based on likeability. The indicator used in this investigation is closer to the latter definition. It may also be useful to investigate measures of popularity based on status. Adolescents may be influenced by the popular crowds in the school who are not members of their immediate social network (e.g., the populars or jocks; Brown & Larson, 2009).

Some of our findings varied across the two high schools. The biggest difference in student body composition between schools was the race and ethnicity of students. It is also possible that neighborhood resources available to students may have also varied across the schools. Unknown differences in number of parks, fast food, and neighborhood safety could play an important role in shaping adolescent's eating and physical activity habits (Kipke et al., 2007). It will be important to amass a larger set of schools that vary on key contextual factors (without confounding them) to truly understand when health-related selection and influence operates. This will be especially important for practitioners interested in applying interventions across a range of settings.

Conclusion

This study suggests that adolescents' school-based friends might influence their BMI and physical activity and that adolescents' health shapes their friendships. This aligns with the Center for Disease Control's guidelines for promoting healthy eating and physical activity by partnering with schools, where friendships are embedded. The current findings suggest two possible avenues that may increase intervention effectiveness. First, if friends become more similar over time in terms of their BMI and physical activity under normal circumstances, it is possible that a focus on friendship groups within interventions might make those interventions more effective in changing adolescents' health. Inclusion of friends within interventions could create new group-level norms and create a mechanism by which the health behaviors and habits targeted in the intervention continue to be reinforced after the intervention ends.

Second, it may be possible to capitalize on friendship-promoting settings within schools, such as courses or extracurricular activities, to deliver health interventions. Organized activities may be particularly effective as they have been shown to help adolescents develop and maintain friendships (Schaefer, Simpkins, et al., 2011) as well as develop friendships with peers they normally would not befriend had it not been for their co-participation (Dworkin, Larson, & Hansen, 2003). The latter may help interventions transcend common social barriers (i.e., friendship clustering by race or gender). By focusing efforts within organized activities, interventions can reach adolescents as well as their friends who can help sustain the intervention aims.

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Table 1

Demographic Characteristics of the Participants and Schools

	School A (n = 667)	School B (n = 1,229)
Individual		
Gender (% female)	46.6	48.1
Race (%)		
White	93.7	4.3
African American	0.0	21.8
Hispanic	0.7	40.2
Asian American	0.6	21.6
Other	4.8	5.0
Age in years *M(SE)*	15.74 (1.18)	16.08 (1.01)
Mothers' education (%)		
Less than high school	10.3	32.1
High school graduate	39.7	19.3
Some college	34.6	28.6
College degree or higher	15.5	19.9
Income in thousands *M(SE)*	48.39 (28.04)	38.39 (23.08)
BMI T1 *M(SE)*	1.29 (0.68)	1.40 (0.74)
Underweight (%)	2.4	1.6
Healthy (%)	76.3	68.8
Overweight (%)	11.2	14.1
Obese (%)	9.6	13.8
Missing (%)	0.4	1.7
BMI T2 *M(SE)*	1.30 (0.68)	1.38 (0.75)
Underweight (%)	2.1	2.7
Healthy (%)	65.1	58.6
Overweight (%)	10.3	11.9
Obese (%)	8.7	11.3
Missing (%)	13.8	15.5
BMI increase T1-T2 (%)	5.7	5.5
BMI decrease T1-T2	5.8	7.5
Physical activity T1	3.79 (2.09)	3.67 (2.03)
Missing (%)	0.00	0.16
Physical activity T2	3.46 (2.03)	3.28 (1.97)
Missing (%)	13.34	14.65
Physical activity increase T1-T2	28.15	27.42
Physical activity decrease T1-T2	39.88	40.28

Parents' obesity (%yes)	24.9	17.6
Parents' co-participation in PA (%yes)	33.1	16.8
Self-Esteem *M(SE)*	4.01 (0.63)	3.97 (0.61)
Breakfast (% yes)	75.2	76.3
Adolescents' sport participation (%yes)	63.6	55.0
Schools		
Type	Public	Public
Location	Rural	Suburban
Region	Midwest	West
Number of students	1,024	2,104
T1 number of friends	3.95	1.94
T2 number of friends	3.29	1.47
Jaccard index	.24	.21
Response rate (%)	76	83
Joined friend network (%)	0.00	0.00
Left friend network (%)	4.90	7.60

Note. T1 = Time 1. T2 = Time 2. T1 number of friends includes the fewer than 5% of respondents whose nominations were constrained to 1 male and 1 female friend at Time 1. Jaccard index calculated as the number of friendships present at both time points divided by the number of friendships present in at least one time point.

Table 2a

Coefficients and Standard Errors of the Behavior Function in the Baseline SAB Model

	School A Coefficient(SE)	School B Coefficient(SE)
Effects predicting BMI		
Rate	0.41 (.06)***	0.36 (.04)***
Linear shape	0.34 (.26)	-0.16 (.13)
Quadratic shape	0.36 (.46)	-0.38 (.21)
Individual attributes		
Female	0.40 (.57)	-0.22 (.27)
Age	0.02 (.25)	-0.01 (.21)
Income	0.01 (.01)	-0.02 (.01)
Hispanic[a]	--	0.46 (.65)
African American[a]	--	-0.23 (.69)
Asian American[a]	--	0.26 (.69)
Other race[a]	--	0.02 (.82)
Self-esteem	-0.37 (.41)	0.25 (.26)
Breakfast	0.23 (.60)	-0.78 (.35)*
Sport participation	-0.97 (.67)	-0.08 (.36)
Parents' obesity	1.09 (.65)	0.69 (.44)
Physical activity	0.07 (.20)	0.15 (.11)
Friend influence effects		
Total similarity	3.23 (1.32)**	1.65 (.73)*
Effects predicting physical activity		
Rate	10.32 (1.09)***	11.34 (1.20)***
Linear shape	-0.10 (.02)***	-0.09 (.02)***
Quadratic shape	-0.03 (.01)***	-0.04 (.01)***
Individual attributes		
Female	-0.08 (.04)	-0.09 (.03)***
Age	-0.01 (.02)	-0.03 (.02)
Income	0.00 (.00)	0.00 (.00)
Hispanic	--	0.09 (.08)
African American	--	0.06 (.09)
Asian American	--	0.13 (.08)
Other race	--	0.12 (.10)
Self-esteem	0.10 (.04)***	0.01 (.02)
Breakfast	0.09 (.06)	0.03 (.04)
Sport participation	0.09 (.05)	0.05 (.04)
Parents' co-participation	0.05 (.05)	0.04 (.04)
BMI	0.01 (.04)	0.03 (.02)
Friend influence effects		
Total similarity	0.45 (.16)***	0.45 (.23)*

Note. [a]Effect not included in the model for school A.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 2b

Coefficients and Standard Errors of the Network Function in the Baseline SAB model

	School A Coefficient(SE)		School B Coefficient(SE)	
Rate	14.46	(.65)***	7.14	(.49)***
Outdegree	-3.66	(.09)***	-5.26	(.16)***
Endogenous network processes				
Reciprocity	2.35	(.07)***	2.71	(.15)***
Transitive triplets	0.42	(.03)***	0.73	(.06)***
Popularity (alter sqrt)	0.14	(.04)***	0.27	(.05)***
Individual attributes				
Grade				
Alter	0.08	(.03)**	0.29	(.07)***
Ego	-0.06	(.04)	-0.16	(.08)
Similarity	1.91	(.13)***	2.86	(.32)***
Race similarity[a]	--		0.96	(.07)***
Female				
Alter	-0.02	(.04)	-0.04	(.06)
Ego	0.00	(.05)	-0.10	(.08)
Similarity	0.14	(.04)***	0.43	(.05)***
Mothers' education				
Alter	0.07	(.02)***	0.10	(.03)***
Ego	-0.01	(.02)	-0.04	(.05)
Similarity	0.23	(.10)*	0.29	(.17)
Sport participation				
Alter	-0.17	(.05)***	-0.08	(.07)
Ego	-0.06	(.06)	0.04	(.09)
Co-participation	0.33	(.05)***	0.35	(.07)***
Nonsport participation				
Alter	-0.08	(.05)	0.12	(.07)
Ego	-0.07	(.06)	0.04	(.09)
Co-participation	0.18	(.08)*	0.08	(.14)
Academic course overlap	0.02	(.00)***	0.13	(.03)***
BMI				
Alter	-0.08	(.05)	-0.02	(.05)
Ego	0.11	(.05)*	-0.10	(.08)
Similarity	0.50	(.16)***	0.48	(.17)***
Physical activity				
Alter	0.05	(.02)**	0.13	(.05)***
Ego	0.11	(.03)***	0.14	(.05)***
Similarity	1.38	(.67)*	2.94	(1.28)*
Gender Interactions				
Alter x BMI ego			-0.02	(.09)
Similarity x BMI ego			0.04	(.10)
Similarity x BMI alter	0.22	(.09)**		

Alter x BMI similarity	0.65	(.26)**		
Similarity x PA similarity	1.43	(.73)*		
Popularity Interactions				
PA alter			-0.06	(.02)***
PA ego	-0.02	(.01)*	-0.09	(.02)***
PA similarity	-0.30	(.13)**	-1.08	(.33)***
Reciprocity Interactions				
BMI ego			1.13	(.26)***
BMI similarity	-1.22	(.37)***		
PA ego	-0.10	(.08)		

Note. [a]Effect not included in the model for school A.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.