Center for Population Dynamics
School of Social and Family Dynamics
Arizona State University
Tempe, Arizona, 85287-3701, USA www.asu.edu/cepod

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Health and the Structure of Adolescent Social Networks

Steven A. Haas

David R. Schaefer

Olga Kornienko

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David R. Schaefer

Olga Kornienko

School of Social and Family Dynamics
Arizona State University

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[*] Address correspondence to Steven A. Haas, School of Social and Family Dynamics, Arizona State University, PO Box 873701 Tempe, AZ 85287-3701, steven.haas@asu.edu.

Abstract

Much research has explored the role of social networks in promoting health through the provision of social support. However, little work has examined how social networks themselves may be structured by health. This paper investigates the link between individuals' health and the characteristics of their social network positions. We first develop theoretical predictions for how health may influence the development and structure of adolescent networks. We then test these predictions using longitudinal analysis of the National Longitudinal Study of Adolescent Health (Add Health). We find important relationships between the health status of adolescents and the characteristics of the social network positions within which they are embedded. Overall we find that adolescents in poor health form smaller local networks and occupy less central global positions than their healthy peers. These results also have implications for social network research, expanding the scope of factors responsible for the network positions individuals occupy.

INTRODUCTION

Researchers from various disciplines have spent the past three decades connecting the health of individuals to the properties of their social relationships. There is compelling evidence that those with meaningful and reciprocal relations with family and peers live longer, healthier lives than their less socially connected peers (Berkman and Glass 2000). Much of that work has examined the health impacts of social support that individuals derive from their social networks (Pescosolido 2001). Others have investigated the role of networks in spreading deleterious health outcomes such as smoking (Christakis and Fowler 2008), sexually transmitted disease (Bearman, Moody, and Stovel 2004), and obesity (Christakis and Fowler 2007).

An important limitation of this work is that most studies presuppose the existence, composition, and structure of social networks without examining the ways in which health may actively influence their creation and maintenance. For example, work that examines the social influence of peers on adolescent smoking largely ignores the fact that adolescents actively choose their friends and that smoking may influence one's relative attractiveness to peers with differential predispositions to smoke. Thus patterns of smoking within a network develop both from social influence and peer selection processes. Despite multiple calls for greater attention to the determinants of network structure and social support, especially regarding the exogenous effects of health (House, Umberson, and Landis 1988; Berkman and Glass 2000), little research has addressed these issues. While previous studies have investigated peer relationships among ill adolescents, only a minority have explicitly examined the structural aspects of their social networks. The few studies that have taken a network approach have done so within the narrow bounds of specific conditions including distress (Hansell 1985), schizophrenia (Cohen and Sokolovsky 1978) disability (Pescosolido 2001) or obesity (Strauss and Pollack 2003). These

studies have found that those in poor health hold less prominent positions within their social networks and that their friends are less connected to one another (Cornwell 2009). However, this work has also only examined network structures in cross-sectional data and thus cannot differentiate between the effect of health on networks and the reciprocal effect of network structure on health. In addition, while the focus on specific diseases can help elucidate particular mechanisms, it can also limit the generalization of processes that may be consistent across a broad array of health conditions.

The current study develops and tests theoretical predictions about why individuals in poor health may be embedded in different social network positions than their healthy counterparts. Specifically, we investigate the longitudinal impact of poor health on change in individual local networks, (e.g. the number of close friends and their interconnectedness), and global networks (which reflect position within the broader network). Characteristics of positions at these two levels correspond with different opportunities and constraints vis-à-vis the types of resources networks provide (Schaefer 2009). Local network characteristics, such as how large or tight-knit the network is, determine access to resources such as social support that are acquired directly from one's social ties. By contrast, global network positions – which reflect whether an individual is included in multiple social circles versus enmeshed in an exclusive group or isolated from much of the network – affect the receipt of information, exposure to new behaviors or diseases, and access to other resources that can diffuse through a network. For instance, the risk of contacting a sexually-transmitted disease is less a function of local position (such as number of partners) than global position, which captures indirect connections to the partners of one's partners (Bearman et al., 2004).

We investigate this question within the context of school-based networks of US adolescents. While no doubt social ties develop in other institutional contexts, for adolescents, schools form the primary hub of their social relationships. Thus we believe that understanding this admittedly circumscribed social space provides a window into a broad swath of adolescent networks and processes that likely generalize to other social contexts. Much of what we describe can also inform the larger issue of health and social networks outside the context of adolescence. However, understanding adolescent school-based networks are themselves important as they shape a wide variety of important social outcomes including academic achievement (Alexander and Campbell 1964; Betts and Morrel 1999), and deviance (Case and Katz 1991).

Our goal is not to refute prior understandings of the link between social networks and health. Rather we aim to augment it with a greater appreciation of networks as emergent phenomena. By failing to examine exogenous health effects, previous research may overestimate the influence of networks on health, as part of the association likely results from reciprocal feedback processes (House and Umberson 1988). In addition, a unidirectional view of networks and health obscures the fact that networks are inherently dynamic phenomena. It is only through a more complex understanding of the bidirectional pathways connecting health and social networks can we fully understand what has become a foundational concept within medical sociology.

BACKGROUND

We presuppose that friendship formation and maintenance among adolescents in poor health must be understood within the normative constraints of their social environment. Fine (1980) identifies three interrelated factors that affect the process of friendship formation and persistence (a) structural opportunities for contact, (b) mutually appealing individual characteristics, and (c)

satisfying interactions. Each of these factors must be present for relationships to develop, and changes in any one of them threatens to weaken or break existing relationships. Integrating health into this framework reveals interrelated and cumulative effects on the size and structure of adolescent social networks.

Opportunities for Contact

Propinquity is the first prerequisite of friendship formation. Relationships are structured around foci that bring people into regular contact with one another (Feld 1981). For adolescents, the school forms the primary context for friendship development (Hallinan and Williams 1989; Cairns and Cairns 1994; Neckerman 1996). Poor health can impose systematic constraints on opportunities for contact with peers. Health-related restrictions on physical activity can make it difficult to participate in activities that serve as foci of friendship formation. For example, substantial physical handicaps are associated with social isolation among children (Cadman et al. 1987). Additionally, poor health may interrupt daily activities and increase school absence, thus diminishing opportunities for social interaction (La Greca 1990). For example, adolescent cancer patients miss 4 times as many school days as their peers (Noll et al. 1991).

Individual Characteristics

Relationship formation also requires that individuals find something attractive in one another that motivates further interaction (Fine 1980). Similarity is one basis for attraction, leading to widespread homophily in relationships (McPherson, Smith-Lovin and Cook 2001). Gender is a primary dimension of homophily from the age of three up through middle to late adolescence (Shrum et al. 1988). Other salient dimensions of homophily include socio-demographic characteristics, school-related attitudes, achievement, aspirations, and risk behavior profiles (Kandel 1978; McPherson et al., 2001; Billy, Rodgers, and Udry 1983; Tolson and

Urberg, 1993; Moody 2001). Such similarities help ensure common experiences and interests that facilitate the communication, support, and overall benefit that relationships provide (McPherson et al. 2001).

The effects of health on this process can be separated into ego effects (e.g., consequences for one's own behavior) and alter effects (e.g., how one's health affects the behavior of peers). Beginning with alter effects; poor health is likely to affect peers' willingness to enter a friendship if it is accompanied by changes in physical appearance (La Greca 1990). Representing what Goffman described as an *abomination of the body* (1963), poor health is more likely to result in stigma if it is readily apparent to others, perceived to be the bearer's responsibility, unalterable or degenerative, or if perceived to be contagious or otherwise put others in harms way (Crandall and Moriarty 1995). With respect to health-induced alterations of physical appearance, it has been observed that children with a visible physical disability experience fewer reciprocated best-friendship nominations compared to children with *invisible* health conditions (e.g. sickle-cell disease) and able-bodied peers (Kleck and DeJong 1983).

As stigma is not confined to the afflicted individual and can easily spread to their non-afflicted associates, adolescents may attempt to avoid this halo effect by not associating with stigmatized persons. Moreover, balance theory, which posits that individuals tend to avoid dissonance in their social relations, would suggest that individuals avoid others whom their friends avoid (Cartwright and Harary 1956). Thus, adolescents may avoid unhealthy individuals in order to maintain harmony with existing friends who see an ill peer as stigmatized. The consequence of this for adolescents experiencing poor health is a restricted pool of potential friends who are open to forming a relationship and smaller overall networks.

Poor health may also influence ego's preferences and behavior when seeking friends if it produces relationship needs or constraints that differ from those of otherwise healthy adolescents. For instance, maintenance of social relationships requires energy and resources. Too many friends can induce stress (Segerstrom 2007) and, when one is unable to reciprocate friendships, create role strain that leads to increased depressive symptoms (Falci and McNeely 2009). Poor health creates additional stressors and reduces the energy that can be devoted to social relationships, making it potentially even more difficult to sustain relationships. Further, individuals suffering from health problems that carry stigma often withdraw from social interactions and relationships that are not believed to be compassionate (Link et al. 1989). Accordingly, we hypothesize that adolescents respond to poor health by maintaining fewer relationships. Although smaller in number, we expect relationships among adolescents in poor health to be just as strong as those among adolescents in better health. Stronger relationships are more likely to survive the strain that accompanies health problems (Cornwell 2009). Thus, we postulate that adolescents will maintain their close friendships at the expense of more casual acquaintances, yielding smaller networks.

Beyond network size, poor health has implications for other structural properties of social networks. Network density captures the interconnectedness among one's friends. Though empirical support is mixed, it has been argued that denser networks produce higher levels of social support by increasing communication and coordination (Hirsch 1979; Stokes 1983). Walker, Wasserman and Wellman (1993) suggest that intensive support (such as chronic health care) is better provided by dense networks while less intensive support (such as companionship) is facilitated by low-density networks.

We expect that health has a positive effect on the density of adolescents' networks. We hypothesize that adolescents in poor health will have denser networks as a consequence of maintaining smaller networks concentrated on close friendships. Networks among close friends are more likely to exhibit transitivity, where one's friends are also friends (Granovetter 1973), than networks of healthy adolescents which containing both close friends and more casual acquaintances. By narrowing the size of their social circles, adolescents in poor health are inadvertently increasing their network density. This is similar to the phenomenon among older adults, who have fewer disconnected ties as the care required to manage health problems deters weaker, non-kin ties (Cornwell 2009). Thus, we hypothesize that *ceteris paribus* adolescents with poor health will be embedded within higher density networks.

Interaction Outcomes

The final step in the development of friendships is interactions that produce positive experiences for the individuals involved, including the exchange of mutually beneficial rewards and the avoidance of costly externalities (Fine 1980). Poor health can affect the consistency of interaction in the same ways that it decreases the opportunities for relationships to develop. When adolescents are routinely absent from school, existing relationships are placed in jeopardy. Without regular interaction, the friends of an unhealthy adolescent may seek out others who can provide them with more consistent friendship (Molm, Schaefer and Collett 2007). Accordingly, youths who missed school due to periodic hospitalizations were less preferred as playmates by their peers (Graetz and Shute 1995).

Adolescents with health problems also often face recurrent modifications in life-style aimed at the alleviation of symptoms and prevention of acute crises (Eiser 1994; La Greca 1990; La Greca et al. 2002). These changes to daily life may include dietary restrictions, complicated

medication regimens, and disease management tasks. For instance, dietary restrictions are important for management of diabetes and activity restrictions to prevent exposure to irritants and allergens are common in asthma management (La Greca 1990). Such aspects of treatment are not only disruptive to normative peer activities but may contribute to self- and peer-perceptions of being "different." In addition, the presence of microstressors, or small daily hassles, can detract psychological and physical energy from youth, lessening their capacity for meaningful engagement with peers (Varni et al. 1989).

Poor health may also lead to asymmetrical resource exchange and imbalance within friendships. As in any form of social exchange, norms of reciprocity require that both members of a friendship derive value from the relationship (Molm et al. 2007). While the members of a dyad may derive different forms of value (i.e., one emotional and the other instrumental), if the exchange of support is perceived to be too one-sided, the relationship may become strained. Health problems may create imbalance either by increasing demands for social support from one's peers or by constraining one's ability to reciprocate in ways required to maintain the friendship.

Health and Global Network Position

To this point we have considered how poor health affects the structure of adolescents' local network, composed of one's friends and the friendships among them. These network features are readily perceptible to adolescents – students know who their friends are and, among them, who is friends with whom – and are often utilized in studies of *ego networks* (e.g., Lin, Ye, and Ensel 1999; Wellman and Wortley 1990). In contrast, students also occupy a position in the broader, school network. Beyond their direct connections to friends, students have many more indirect connections to other students in the school through friends of their friends. However, the nature

of the indirect connections to others in the global network can differ greatly. For example, student A may have five densely-connected friends but be part of a rather isolated clique, with only one member regularly interacting with students outside the clique. Student B may also have five densely-connected friends, but the friends mingle in somewhat different social circles. Students A and B have the same local network structure but their global positions differ widely. Student B is likely to be more informed about other students and events within the school than A. B likely has greater exposure to ideas and behaviors that diffuse through the school network; whereas A's access to information is restricted by the single clique member with ties outside the clique.

We hypothesize that one's location within the broader, school network is also affected by health. The effects of poor health on global position are based on local friendship processes (described above) whose effects ripple through the network. For instance, health is a status characteristic that can affect others' perceptions of one's friendship potential. For example, youth suffering from illness are perceived to be less desirable as friends (Richardson 1983). All else being equal, when given the option, adolescents would choose healthier peers over less healthy ones. Gould (2002) suggests that individuals prefer to be attached to others of high status, but forfeit that attachment if it is not reciprocated. Thus, "individuals face a trade-off between attaching themselves to *desirable* alters and attaching themselves to *available* alters" (Gould 2002:1150). If unhealthy adolescents with low-status attempt to form friendships with higher-status, healthy peers, their gestures are less likely to be reciprocated because high-status peers receive more offers of friendship than they can accept. Beyond smaller networks, a consequence of this process is that adolescents with poor health are more likely to form relationships with peers of low status. Lower status peers are themselves less attractive as friends, with fewer peers

willing to reciprocate their friendship and making an ill peer who can reciprocate relatively more attractive to them. Indeed, research suggests that such stigmatization processes lead to homophily on body size among adolescents (Crosnoe et al. 2008). Thus, we expect that adolescents in poor health are more likely to be friends with adolescents who are lower in status. This reciprocity-induced homophily can affect global network position through two processes.

Homophily on health status may evidence itself in the structure of cliques, or informal peer groups, which will vary based on the health of their members. Given at least some preference for high-status (e.g. healthier) friends, adolescents are less likely to choose friends from cliques of low-status (less healthy) peers. This leaves more friendships between cliques of healthier adolescents and leaves their less healthy peers in more marginalized positions and less able to indirectly access others in the network.

Poor health may also impact global network position through its effects on formal group memberships. The risk of network marginalization is expected to be greater to the extent that poor health prevents adolescents from participating in group activities. Groups create the possibility for direct ties to fellow group members in addition to indirect ties to fellow members' friends outside the group (Moody 2001). Moreover, since groups draw their members from distinct niches (McPherson 1983), reductions in activities will diminish the likelihood of forming ties to other in different niches or network regions (which enhance one's global centrality). Less healthy adolescents may form just as many relationships within the groups they join, but their global centrality may be lower.

Hypotheses

In synthesizing the preceding discussion, we propose four hypotheses about the effects of poor health on the social networks of adolescents:

Hypothesis 1. Poor health will be negatively associated with network size: adolescents with poor health will have fewer network ties than their healthier peers.

Hypothesis 2. Poor health will be positively associated with the probability of being a social isolate.

Hypothesis 3. Poor health will be positively associated with friendship network density.

Hypothesis 4. Poor health will be negatively associated with adolescents' position within the global friendship network.

METHODS

This study uses data from waves 1-2 of the National Longitudinal Study of Adolescent Health (Add Health), which investigates the health, social contexts, and relationships of adolescents in the United States. Add Health is a widely used data set that provides a unique opportunity for investigating the associations between health and social networks in a nationally representative sample of adolescents. Add Health uses a multistage, clustered sampling design, in which, a nationally representative sample of 132 middle and high schools was selected, and then from the students attending these schools, a representative sample of adolescents was chosen for participation (Bearman et al. 2004). During the in-school survey, conducted in September 1994- April 1995, all students in attendance were given self-administered questionnaires. A sub sample of participants from the initial school survey was selected for an in-depth, in-home component, in which both adolescents and their parents completed questionnaires between April-December 1995. Wave 2 in-home surveys we then collected from April-August 1996. Because we are interested in both ego and global networks we limit our analysis to respondents in 16 saturated schools (in which all students were targeted for in-home interviews and thus provide complete network data). Within the 16 saturated schools 4,195 adolescents

participated in the in-school data collection. For 127 students coding errors involving student IDs precludes matching network and survey data leaving 4,068 students with valid wave 1 data on friendship networks, health and control variables. Because we are interested in the longitudinal impact of health network size and structure we further constrain our analysis to those respondents also participating in the subsequent in-home survey at wave 2. From the 16 saturated schools 2,065 of students were present in the requisite waves. Of the 2,003 students not participating in wave 2, 1,585 were juniors and seniors during in-school wave 1 who would have graduated in the two-year period between the data collection points and thus ineligible for follow-up. The remaining 318 cases were lost to follow up due to unknown reasons. We deleted additional 5 students who were missing proper sampling-weights. The final analytic sample includes 2,060 adolescents for.

Measures of Adolescent Friendship Networks

As part of the surveys, participants received a roster of all students enrolled in their school and their sister feeder school and were asked to nominate up to five male and five female friends. In some instances, students nominated friends who were not found on the roster. Unless otherwise noted, we excluded such nominations from these analyses, as no data were available on the outgoing ties – and hence network position – of out-of-school friends. The networks formed by these nominations were used to construct the measures of local and global network position. We constructed network indices for two time points: baseline (wave 1 in-school) and subsequent in-home wave 2.[1]

Out-degree and in-degree are used to describe the size of local networks. *Out-degree* is the number of outgoing friendship nominations that a focal adolescent makes. Given the network data collection strategy, each adolescent was able to nominate up to 10 friends. It should be

noted that we calculated this index based on the complete set of nominated friends – identifiable and unidentifiable – since information about friends' ties is not required. *In-degree* is the number of incoming friendship nominations that a focal adolescent receives. Given that any number of students could potentially nominate a focal adolescent, this index can range between zero and the number of other students attending a school. We also created a dummy variable which indicates whether the adolescent received no in-coming nominations and is thus a social isolate. The contrast between incoming and out-going nominations provides insight into how adolescent's view their social ties compared to how they are viewed by peers. Difference in in-degree and out-degree also shed light on whether health-related differences in network size likely derive from ego or alter effects. If health problems lead adolescents to have smaller networks than what they desire or is normative for their age, they may be less discriminating when completing the Add Health survey and include weaker friendships. This would impact outgoing but not incoming nominations.

Network *density* was calculated by dividing the number of ties between one's alters (e.g., friends) by the total number of ties possible between alters (calculated as the number of alters, *n*, times *n*-1). The density of isolates' friendship networks is undefined, thus such cases were excluded in the density analysis. The distribution of density had a positive skew; to better approximate the normal distribution we transformed it by adding one to the density score and taking the natural logarithm.[2]

Global network structure is operationalized with two measures: *influence domain* and *Bonacich centrality*. These measures are similar to in-degree and out-degree in that they index the volume of ties emanating from an adolescent (Borgatti and Everett 2006). They differ from degree-based measures in that they consider both direct and indirect connections to others.

Influence domain and Bonacich centrality capture different aspects of centrality and the extent to which students are active within the broader school environment, not just with their group of friends. Using outgoing ties, Bonacich centrality weights ego's centrality by the centrality of his or her alters (Bonacich 1987). This form of centrality is high when students are connected to others who are themselves well-connected and is often used as an indicator of sociometric popularity (Bonacich 2007). For example, a student with 3 friends, who are themselves central in the network, is more central than a student with 3 friends located in more peripheral network positions. This metric is calculated according to the following formula:

$$\text{Bonacich Centrality of X } (\alpha,\beta) = \alpha * (\boldsymbol{I} - \beta * X)^{-1} X\mathbf{1}$$

where **X** contains all friendship nominations in the form of an adjacency matrix, α is a scaling factor (determined mathematically to allow the equation to be solved), and β is a power weight reflecting the degree of dependence of actor's prestige on the extent of prestige of the alters to whom the ego is connected (equal to 0.1 in Add Health). **I** is an identity matrix and **1** is a column of 1s.

Again if less healthy adolescents tend to be less discriminating when nominating friends, then measures of centrality based on outgoing ties (such as Bonacich centrality) may be artificially inflated. However, centrality measures based on incoming ties would not be affected. Thus, examining centrality through incoming and outgoing ties separately is important for assessing and overcoming measurement error due to social-desirability. Therefore, we also consider influence domain, which is based on the number of incoming ties (i.e., others who nominate ego directly or indirectly). Influence domain measures the number of alters who can reach ego though direct and indirect connections. For example *i* can reach *j* if *i* has a direct tie to *j* or if *i* has a tie to *k* who has a tie to *j*. Given that this measure is sensitive to the size of a school

(i.e., students in larger schools could have a larger number of direct and indirect incoming nominations), it was standardized by dividing by the size of the network in each school. While we expect health conditions to lead to more marginal positions in both regards, it is possible that the strength of effects varies. Moreover, to the extent results for the two measures of global position converge, we are confident that response bias is not problematic for our inferences.

Measures of Health and Control Variables

We examine the impact of adolescent's poor health status using self-rated health status (SRH), dichotomized as 0= excellent/very good; 1=good/fair/poor. Among adults, self-rated health is a reliable and valid measure of general physical well-being (Idler and Kasl 1991). Recent research has found that among adolescents, SRH is moderately stable over repeated observations and that it captures both enduring and transient physical and psychological dimensions of well-being (Fosse and Haas 2009; Boardman 2006). In Add Health, SRH was gathered from adolescents at the in-school and in-home surveys. To minimize missing data we used the wave 1 in-home value for those adolescents missing in-school health reports.

The following control variables were included in the analyses: age (measured in years), race (White, African-American, and other), and Hispanic ethnicity. In addition, two variables were created to control for respondents' socioeconomic background: 1) a dummy variable of whether the family received public assistance, obtained from the parental report, and a series of dummy variables (less than high school, high school (referent), and more than high school) capture the highest level of educational attainment of the highest educated residential parent. Finally, family structure was measured by a series of dummy variables differentiating among adolescents who resided with two biological parents, a single parent, or other type of households. Descriptive statistics for all variables used in the analysis are provided in table 1. There was

some missing data on covariates (particularly for the public assistance variable). Missing data we handled using multiple imputation via the Proc MI procedure in SAS (Proc MI).

[Table 1 about here]

Analytical Strategy

To examine the effect of poor health on the properties of adolescents' peer networks we estimate longitudinal residual-change models. Residual-change models (aka auto-regressive models) are among the most frequently techniques to examine change over time. The residual-change approach involves modeling the outcome of interest at time 2 while controlling for the level of that same variable at time 1. This provides more compelling evidence as to whether poor health significantly impacts social network structure and position than traditional cross-sectional regression models as only predictors of change in the rank order of observations are typically statistically significant. Those variables that predict systematic monotonic change among all observations typically remain in-significant (Meredith and Tisak 1990). In-degree, out-degree, density, influence domain and Bonacich centrality were estimated using linear models, while social isolate status was estimated using logistic regression. In each model, the network variable at wave 2 is regressed on baseline poor self-rated health, prior network variable status, and additional control variables. We also tested models without adjustment for baseline network status and the results are not substantively different. Given the complex clustered nature of Add Health data, sampling weights and survey regression procedures were used for all analyses. Regression estimates derived from multiple imputations were combined using the MIANALYZE procedure in SAS.

RESULTS

Local Networks

The results of the regression of adolescent's local (ego-centric) network are presented in Table 2. The impact of poor health on change in network size varies greatly whether it is measured on the basis of incoming versus outgoing ties. Using out-going ties (first set of columns) we find no statistically significant impacts of poor self-rated health on the number of friendship nominations made. However, when considering in-coming nominations (second set of columns) we find that adolescents who reported poor self-rated health at baseline received fewer subsequent friendship nominations than their healthier peers. Adolescents with poor self-rated health at baseline had on average .20 fewer in-coming nominations compared to their healthy peers, net of prior number of incoming ties. This is equivalent to approximately a 7% reduction from the mean number of incoming nominations at wave 2. Similarly, adolescents in poor health were significantly more likely to be a social isolate at wave 2 (third set of columns). Poor health increases the odds of becoming a social isolate by nearly 20% (odds-ratio = $e^{0.18} = 1.197$). These findings are consistent with Hypotheses 1 and 2 which predicted that poor health would be negatively associated with network size and positively associated with odds of being a social isolate. We also find that non-white adolescents experience greater declines in incoming and outgoing friendship nominations and are more likely to become social isolates relative to their white peers. Adolescents from single-parent families experienced fewer incoming nominations than those from intact families. Family socioeconomic status was not significantly associated with change in local network parameters over time.

[Table 2 about here]

Analysis of network density is presented in the last set of columns in Table 2. In contrast to the results for network size, we find no support for hypothesis 3 that poor health is associated with increased network density. Baseline poor self-rated health was not associated with

subsequent differences in network density. Older adolescents as well as African Americans had lower social network density than their younger and white peers.

Global Network Position

Table 3 presents estimates of the impact of health on adolescent's global network position as measured by influence domain and Bonacich centrality. The results for influence domain and Bonacich centrality generally provide support for hypothesis 4 which predicted that adolescents with poor health would occupy less central locations within the global network. The results for the analysis of the impact of poor health on influence domain are presented in the left hand columns of Table 3. We find a significant negative association between poor self-rated health at baseline and subsequent influence domain. Influence domain represents the proportion of students in the school who can reach ego directly or indirectly. The coefficient of -.02 indicates that students in poor health are reachable by 2% fewer adolescents net of their prior reachability. Thus, adolescents with poor self-rated health occupy increasingly less central positions within their networks over time. We further find that racial/ethnic minorities, those from non-intact families, and those with less educated parents also occupied less central positions within their networks based on influence domain.

[Table 3 about here]

Finally, the results for the last index of global network position considered, Bonacich centrality, are presented in the right hand columns of Table 3. Based on outgoing nominations, Bonacich centrality affords a more nuanced picture of individuals' global position because it weights ego's centrality by the centrality of the friends he or she nominates. Worse SRH (b= -0.05) is significantly and inversely associated with Bonacich centrality at wave 2 net of prior centrality. Adolescents reporting poor self-rated health at baseline nominated fewer friends, who

themselves tended to nominate fewer friends, than adolescents reporting better health. While older kids had higher Bonacich centrality, Hispanic adolescents occupied less central network positions.

DISCUSSION

Understanding social networks and how their structural properties facilitate or inhibit the provision of social support is critical to understanding the social context of health and well-being and has been the subject of substantial social science research over the past three decades. However, to date, little research has investigated, conceptually or empirically, how an individual's health status may act as an important determinant of the structure of their social network. This study fills this gap by developing theoretical predictions about the influence of health on adolescent social networks and testing them with high quality longitudinal data. We find that adolescent health has significant impacts on both local ego-centric network structure as well as position within the larger global network. The above analysis provides support for hypotheses 1 and 2, clearly showing that net of socio-demographic background and baseline network characteristics, adolescents who report poor self-rated health at baseline have fewer subsequent friends in their social networks and are significantly more likely to be social isolates. This is driven entirely by differences in the number of in-coming friendship nominations. As they nominate the same number of friends as their healthier peers, adolescents with worse health do not necessarily perceive themselves as having fewer friends. However, they are less likely than their healthier peers to be nominated by others. This would suggest that alter-related behavior, rather than the preferences and actions of adolescents themselves, may be most responsible for the adverse impact of poor health. Contrary to hypothesis 3, initial health status does not appear to impact change in network density. We also find support for hypothesis 4, that

adolescent health also has significant impacts on adolescent position within the larger global network. Adolescents with poorer health occupy more marginal and less central positions within their larger networks, based on multiple measures of global centrality including influence domain and Bonacich centrality.

The findings are important for a number of reasons. Empirically, the presence of reciprocal feedback effects from heath to social network structure suggests that prior estimates of the impact of networks on health may be overestimates. This suggests that future analyses of health and social networks take advantage of more complex dynamic modeling procedures. For example, new statistical techniques have been developed to model the co-evolution of health-related behaviors and social networks (Snijders 2005). Such models allow for a much more nuanced understanding of the simultaneous effects of social influence and peer selection processes in determining the distribution of health behavior and conditions within networks.

The finding that health can shape social networks also has important implications for a wide variety of social processes and outcomes. For example, a growing body of research has shown that poor health status has a detrimental impact on the educational achievement and attainment of adolescents (Needham, Crosnoe, and Muller 2004; Case, Fertig, and Paxson 2005; Haas and Fosse 2008). Given the important role of relationships in mediating the adverse effects of health insults and the long-observed impact of peer influences on academic achievement (Alexander and Campbell 1964; Duncan, Haller, and Portes 1968), social network processes may be an important mechanism linking health and educational outcomes. For example, their greater social isolation and marginalization within the school may reduce sick adolescent's attachment to school, negatively impacting achievement. Future research would be wise to examine the potential mediating role of social networks in health-related selection into lower educational

strata. In addition, peer relationships may be an important point of intervention to improve the social functioning and academic outcomes of children and adolescents with health problems.

The findings also have important implications for social networks researchers. Although the association between health and network position may be apparent to health scholars, social network researchers typically take a more structural approach that treats individuals as homogenous actors. While social network researchers have recognized that individual characteristics matter for some network processes (i.e., homophily), they have only recently begun to explore whether the occupation of network positions is itself a product of individual attributes. Recent suggestions have been made to consider how social development (Schaefer et al. Forthcoming), cognitive processes (Robins and Kashima 2008), and psychological predispositions (Kalish and Robins 2006) affect the types of positions individuals occupy in a network. The current study identified health as a key individual characteristic affecting adolescent social position and provides additional insight to the processes through which individuals sort themselves into network positions.

There is reason to suspect that much of the processes outlined above are strongly structured by gender norms. As such the social impact of poor health needs to be understood within the gender-specific developmental context. In additional analysis (not shown) we tested for interaction effects between gender and poor self-rated health. The results revealed no significant gender differences in the effect of poor self-rated health on social networks structure or position. This may due to true gender invariance in the impact of health on networks. Alternatively, Boys and girls may be equally affected by health problems, though the effects may operate through different mechanisms. For example, it has been shown that treatments for health problems that limit physical growth and strength have greater social consequences for boys,

whereas those reducing physical attractiveness are more distressful for girls (La Greca 1990; Hurtig and White 1986; Wasserman et al. 1987). Similarly, La Greca (1990) has noted that health-related restrictions on physical activity might be differentially consequential for boys' and girls' peer relations. Unfortunately, the limited information on specific health conditions and their low prevalence in the Add Health sample prohibit such analysis. Further research is needed to explore gender differences in the mechanisms linking health to networks.

The chief limitations of this study derive from constraints of the data. First, the measure of adolescent health is somewhat limited. While self-rated health has been shown to be a reliable measure of overall health among adults and adolescents, detailed data on specific health problems and conditions would provide greater ability to disaggregate the specific mechanisms linking illness to network size and structure. While Add Health includes some information on specific chronic conditions, the prevalence in the data are inadequate to support further in-depth analysis especially vis-à-vis gender differences. In addition, due to the survey design, information on specific health conditions is only available for respondents who first reported problems with limb functioning.

A second limitation is that we are only capturing the school-related dimension of adolescents' social experience, due to the artificial network boundary imposed by the study design (Marsden 2005). While the school is a primary hub of adolescent's social relationships, other institutions and environments in which they are embedded clearly matter. This may be particularly important for the social adaptation of chronically ill youth who may feel constrained and isolated within the normative context of the school and seek out alternative sites of friendship formation and social support. This may include joining formal or informal groups associated with their condition, where shared health experiences facilitate social relationships.

Thus, social deficits experienced in school may be offset by non-school peer relationships. However, in additional analysis (not shown) we find adolescents in poor health are no more likely to have nominated friends outside of the school than their healthier peers. We also estimated models with and without controls for the number of non-school friendship nominations. This did not meaningfully change the results. Thus, we find no evidence that restricting the social network to within the school significantly affects our results.

This study has focused on friendship formation and maintenance of adolescents. Though many of the specifics of this discussion are unique to that population and social context, we believe that much of the underlying process and mechanisms described above are generalizable to adults. That is, adults faced with health problems face many of the same constraints in regard to illness-induced limitations on opportunities for social interaction, stigmatization, and adverse interaction outcomes (see Cornwell 2009). At the same time the impact of poor health on social network structure may be more pronounced in adolescence given the more tenuous and fluid nature of their friendships. Adults on the other hand, may benefit from the greater probability of having long-standing relationships and the prior winnowing of the weaker, less secure, and thus less supportive ties in their friendship networks. Older adults in particular may have different experiences as chronic health problems become common and normative among peers. More research is needed to elaborate the common and unique dimensions to these processes at different points in the life course.

The results of this study highlight the need for a more complex, and dynamic, understanding of social networks and health. Such an understanding should not only illuminate the ways in which various network structures facilitate or inhibit the provision of health-related social support, but recognize that social networks are themselves emergent, a product of health

conditions among other factors. It is only through such a dynamic reciprocal approach that researchers can begin to fully appreciate the rich and complex processes linking health and human social relationships.

NOTES

1. Network data was collected as part of the first in-home survey, however many students were only allowed to nominate one male and one female friend, for a maximum of two alters. To maintain consistency with the school survey and provide a better representation of friendship networks, we use the more complete data available at school and the home two survey.

2. 85 Students nominated at least 1 non-uniquely identifiable alter. These cases are not included in the analysis of in-degree, Bonacich centrality, density, and influence domain which require indentifying unique alters.

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Table 1. Descriptive Statistics (Add Health 1994-1996).

	%	Mean	S.D.	% Missing
Good/Fair/Poor SRH	36.2			2.5
Excellent/Very Good	63.8			
Network Variables				
In-Degree Wave 1		4.30	3.6	0.0
In-Degree Wave 2		2.90	2.7	0.0
Out-Degree Wave 1		6.80	3.4	0.0
Out-Degree Wave 2		5.80	2.8	0.0
Isolate Wave 1	8.5			0.0
Isolate Wave 2	27.8			0.0
Density Wave 1[a]		0.16		8.5
Density Wave 2[a]		0.17		27.8
Bonacich Centrality Wave 1		0.93	0.7	0.0
Bonacich Centrality Wave 2		1.11	0.9	0.0
Influence Domain Wave 1		0.53	0.2	0.0
Influence Domain Wave 2		0.18	0.2	0.0
Control Variables				
Age		16.11	1.5	0.1
Female	50.5			2.5
Hispanic	20.1			0.3
White	60.2			0.3
African American	16.9			0.3
Other Race	22.9			0.3
Parental Education <12 Years	12.5			3.0
Parental Education 12 Years	31.9			3.0
Parental Education >12 Years	55.6			3.0
Public Assistance	6.2			18.1
Two-Parent Family	73.8			0.3
Single Parent Family	22.2			0.3
Other Family	4.0			0.3

[a] Density is undefined for social isolates.

Table 2. Regression of Adolescents' Local Friendship Network (Add Health 1994-1996).

	Out-degree		In-degree		Isolate[e]		Density	
	b	S.E.	*b*	S.E.	*b*	S.E.	*b*	S.E.
Good/Fair/Poor SRH[a]	-0.10	0.10	-0.20**	0.06	.18**	0.06	-0.01	0.01
Wave 1 Out-degree	0.13***	0.02						
Wave 1 In-degree			0.32***	0.02				
Wave 1 Isolate					1.77***	0.02		
Wave 1 Density							0.19***	0.04
Age	-0.22*	0.10	-0.12*	0.06	0.05	0.08	-0.02***	0.00
Female	0.32	0.19	-0.21	0.14	0.05	0.11	0.01	0.01
Hispanic	-0.40*	0.17	-0.26**	0.10	0.26**	0.09	-0.00	0.01
African American[b]	-1.59*	0.64	-0.98**	0.35	1.19*	0.49	-0.06***	0.02
Other Race[b]	-1.02***	0.16	-0.30	0.16	0.33	0.21	0.00	0.01
Single Parent[c]	-0.14	0.14	-0.14*	0.07	0.15	0.10	0.01	0.01
Other Family[c]	-0.44	0.27	-0.33	0.20	0.38	0.23	0.01	0.02
Parental Educ. <12 Years[d]	-0.06	0.24	-0.07	0.16	0.26	0.16	0.02	0.02
Parental Educ. >12 Years[d]	0.14	0.18	0.08	0.13	0.00	0.13	0.01	0.01
Public Assistance	-0.03	0.22	-0.29	0.27	0.13	0.32	-0.03	0.02
N	2060		2060		2060		1487	

[a] reference category is excellent/very good
[b] reference category is white
[c] reference category is two-parent families
[d] reference category is 12 years
[e] results of logistic regression
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$ (two-tailed tests)

Table 3. Linear Regression of Adolescents' Global Friendship Network (Add Health 1994-1996).

	Influence Domain		Bonacich Centrality	
	b	S.E.	*b*	S.E.
Good/Fair/Poor SRH[a]	-0.02*	0.01	-0.10**	0.03
Wave 1 Influence	0.21***	0.04		
Wave 1 Centrality			0.33***	0.02
Age	-0.01	0.01	-0.06**	0.02
Female	-0.01	0.01	-0.03	0.04
Hispanic	-0.07***	0.02	-0.03	0.04
African American[b]	-0.15***	0.04	0.04	0.12
Other Race[b]	-0.14***	0.04	0.15***	0.04
Single Parent[c]	-0.02*	0.01	-0.05	0.04
Other Family[c]	-0.05*	0.02	-0.07	0.08
Parental Educ. <12 Years[d]	-0.04*	0.02	0.05	0.07
Parental Educ. >12 Years[d]	-0.02	0.01	0.01	0.05
Public Assistance	-0.03	0.02	-0.00	0.13
N	2060		2060	

[a] reference category is excellent/very good

[b] reference category is white

[c] reference category is two-parent families

[d] reference category is 12 years

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$ (two-tailed tests).