Chronic Health Conditions and Adolescent Friendship: Perspectives from Social Network Analysis

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ABSTRACT

Objective: The current study uses methods from social network analysis to examine the relationship between chronic health conditions (CHC) and adolescent friendships. Particular attention is given to the processes of peer marginalization, peer withdrawal, and homophily related to CHC. ***Methods:*** Exponential random graph models were used to investigate the extent to which CHC is associated with patterns in adolescent friendship connections, while controlling for important social network properties and covariates. The study uses cross-sectional data from six small U.S. high schools ($N = 461$) within the National Longitudinal Study of Adolescent to Adult Health. ***Results:*** Findings demonstrate no significant differences between adolescents with CHC and adolescents without CHC in the number of incoming friendship nominations (peer marginalization) or outgoing friendship nominations (peer withdrawal). In addition, similarity in CHC (homophily) was not significantly related to friendship between two individuals. ***Conclusions:*** In sum, the presence of adolescent CHC was not significantly associated with adolescent social network structure, including peer marginalization, peer withdrawal, and homophily related to CHC, after controlling for alternative social network processes. Although previous literature suggests that adolescents with CHC experience negative social consequences, the current findings demonstrate that the social network structure of adolescents with CHC did not differ significantly from that of their peers without CHC. Thus, findings from the current study suggest that CHC are not related to objective reductions in social connections.

Keywords: social networks; adolescents; chronic health; friendships

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Developmental research highlights the importance of peer relationships to adolescent wellbeing and healthy development (1, 2). Increased autonomy and time with peers contribute to the salience of friendships during this developmental period (3, 2). Consequently, a lack of friends is associated with increased depression and decreased self-worth in adolescents (1, 2). According to developmental theories (4), adolescent friendships and health are interrelated, such that health impacts social outcomes (e.g., friendships), and vice versa. Empirical research supports this relationship and adolescent friendships have been shown to form around health indicators such as obesity (5), mental health (6), and substance use (7). Given the interdependence of friendships and health, in tandem with the critical role of friendships during adolescence, there is a continued need to investigate the complex relationship between health indicators and patterns in adolescent social connections.

Recent advances in the field of social network analysis allow for the interdependent nature of adolescent friendships and health to be explicitly modeled. Social network methods embed adolescents within the social structure of their environment (e.g., typically the school peer context) and estimate the extent to which individual attributes (e.g., health indicators) are related to social structure (e.g., patterns in friendship connections). The primary strength of social network designs rests in the ability to model the ways through which individual attributes are related to social outcomes, while also controlling for features of the social network itself. For example, friendships are more likely between individuals with shared sociodemographic attributes such as gender and race (8), and between individuals with shared social connections (i.e., transitivity; 9). Further, adolescents differ in sociability and popularity, often related to

particular health attributes. Specifically, adolescents who are obese (5) or have poor mental health (6) are socially marginalized and isolated, while adolescents who use substances, particularly alcohol, are often popular (10).

Findings demonstrate that adolescents with chronic health conditions (CHC) experience feelings of social isolation (11-13) and engage in increased levels of health risk behaviors (14, 15). This suggests that adolescents with CHC are particularly vulnerable to the negative repercussions of social isolation, compounded by engagement in health risk behavior. Despite this considerable vulnerability, no study to date has examined the extent to which CHC is associated with patterns in friendship connections during adolescence. Knowledge of the relationship between CHC and friendship would allow researchers to better design effective intervention strategies to support and enhance the wellbeing of this vulnerable population. Thus, the current study employs a novel social network design to investigate if CHC are associated with the structure of adolescent friendships.

Adolescent chronic health conditions in social context.

Nearly one out of four youth aged 17 years or younger in the U.S. suffers from a chronic health problem (16, 17). Although definitions vary (17), CHC typically involve a health problem that does not resolve within three months, affects a youth's normal activities, and require prolonged or frequent treatment from a medical provider. CHC impact adolescent development in multiple domains, and research demonstrates that adolescents with chronic health experience social consequences, such as reported difficulty developing and maintaining friendships and feelings of social isolation (12). In addition, CHC have been associated with poorer quality peer relationships and increased levels of social anxiety (18). Though previous research has highlighted negative social consequences surrounding CHC, the current study is the first known effort to parse apart the underlying social structure of adolescents with CHC.

Social network methods are particularly well-suited to investigate the intersection of CHC and adolescent friendships due to their ability to deconstruct adolescent social networks in three critically important ways. Social network data utilize friendship nominations, wherein adolescents are asked to identify peers from their school whom they consider to be a friend. These nominations are subsequently separated into incoming and outgoing friendship ties, thereby allowing researchers to examine the specific associations between CHC and adolescent friendship. First, social marginalization of adolescents with CHC can be tested by comparing the likelihood of friendship ties directed toward adolescents with chronic health, versus ties directed toward adolescents without CHC. Second, social withdrawal can be tested by comparing differences in the likelihood of sending friendship nominations according to whether the adolescent has a CHC. Lastly, homophily, or similarity in CHC status, can be tested in order to determine if friendships are more likely between two individuals with similar CHC status (e.g., either both with or without CHC) than friendship between adolescents without this in common.

Although previous literature suggests that adolescents with CHC experience feelings of social isolation, the current study uses a novel social network approach to examine if the objective social network structure of adolescents with CHC differs from that of their peers without CHC. Specifically, the current study asks the following research questions: 1) Do adolescents with CHC receive fewer friendship ties (i.e., social marginalization) than adolescents without CHC? 2) Do adolescents with CHC send fewer friendship ties (i.e., social withdrawal) than adolescents without CHC? 3) Is friendship more likely between two adolescents with similar CHC status (i.e., homophily) than between adolescents who differ on CHC? By illuminating the extent to which CHC are related to objective measures of social connections, the current study offers valuable insight into effective strategies to support the social wellbeing of adolescents with CHC.

Method

Participants and Procedure

The current study is based on students within The National Longitudinal Study of Adolescent to Adult Health (19), a nationally representative multi-wave panel study of adolescents in grades 7-12 at the onset of the study in 1994. Add Health consists of a sample of 80 high schools and 52 middle schools from the US, selected with unequal probability of selection, stratified by region of country, urbanicity, school size, school type, and ethnicity (N = 90,118). Wave I in-school interviews were conducted with 132 schools in 1994, and a sub-sample of students underwent more comprehensive Wave I in-home interviews approximately 6 months later. The current study uses data obtained during the Wave I in-home interviews, as CHC questions were limited to this measurement occasion. 16 schools administered complete friendship surveys as part of the Wave I in-home interviews, a requirement of the present analyses. Of these schools, two were eliminated for large sample size (n = ~ 1000), which adds computational challenges to the analyses (20), and seven were eliminated for being designated as middle schools (i.e., grades 6-8) or special education schools. One additional school was excluded due to issues with model convergence. As a result, the current study is based on students within six high schools (i.e., grades 9-12) in the Wave I in-home sample of Add Health (N = 461). Models were run separately by school and then aggregated across schools via the meta-analysis technique of Snijders & Baerveldt, 2003 (21). Despite the age of the data, Add Health remains one of the most comprehensive sources of friendship and health data, and research continues to demonstrate the relevance of these data to the study of friendship network characteristics and a diverse range of adolescent health indicators (22).

Measures

Friendship ties. Adolescents were asked to identify their five closest female and five closest male friends from a provided roster of students within their school. ID codes were used to link adolescents to nominated friends, thus creating friendship ties. Nominations for out-of-school friends were not considered, as data was not collected on these individuals. In this way, friendships were restricted to those occurring within the school in which the adolescent is enrolled, allowing for the formation of multiple complete networks of adolescents, a requirement of the analyses (26).

Chronic health conditions (CHC). CHC are measured through three questions on various forms of CHC, including asthma, migraine headaches, and diabetes. A binary indicator of CHC was created, such that adolescents with no CHC were given a score of 0, and adolescents with one or more CHC were given a score of 1. Data on CHC was obtained from the parent questionnaire administered as part of Wave I in-home survey.

Demographic control variables. In order to provide accurate estimates of associations between adolescent friendships and CHC, other potential predictors must be controlled (9, 23). Therefore, the proposed study controlled for important variables related to friendship formation or CHC, including grade level, gender, ethnicity, and depression. Grade level was coded as grade at Wave I and ranged from 9-12. Gender was coded dichotomously as male or female. Ethnicity was measured through a binary indicator of Hispanic self-identification (0 = no, 1 = yes). Depression was measured with an 18 item, 3-point Likert scale from the Center for Epidemiologic Studies Depression Scale included in Add Health (Cronbach's alpha: 0.84).

Missing data. Variables within the current study displayed relatively low rates of missing data (3.5% on average). As a result, the school mean was imputed for continuous variables and the school mode was imputed for categorical variables. Methods for treating both attribute and friendship tie missingness within the ERGM framework are underdeveloped (23, 7),

and the use of school-wise mean and mode imputation is commonly used with small rates of missing data in ERGM studies (25, 5).

Analysis

The current study investigated the relationship between CHC and adolescent friendships using cross-sectional exponential random graph models (ERGMs; 26) carried out in the "ergm" package (27) in R Language and Environment for Statistical Computing (28). Friendships in social network models are auto-correlated and therefore violate assumptions of independence, thus precluding the use of conventional statistical techniques. The ERGM statistical framework, however, takes dependencies between friendship partners into account and predicts the likelihood of friendship connections based on individual, dyadic, and structural features of the network (i.e., the way individuals within a social network are connected). ERGMs produce parameter estimates that can be interpreted as the log odds of a friendship tie conditional on all other ties. ERGMs have recently been used to examine adolescent friendship network structure in relation to health indicators such as obesity (5) and mental health (6), however the proposed study is the first known effort to apply a social network approach to the relationship between CHC and adolescent friendships. The current study was approved by the Institutional Review Board of the author-affiliated university.

Overview of Modeling Process. The outcome of an ERGM is dichotomous: the presence or absence of a friendship tie between all possible dyads within a social network. All models include an edges term, which represents the overall probability of a friendship tie. ERGMs represent social networks as graphs of nodes (i.e., individuals within a network) and edges (i.e., ties between friendship partners). For every ERGM, the number of nodes is fixed to the number of observed individuals within the network. The observed network is treated as one possible pattern of friendships out of a large set of possible patterns. The range of possible networks, and

their probability of occurrence is represented by a probability distribution on the set of all possible graphs with the observed number of nodes.

Theoretically-driven model parameters are estimated in order to determine the attributes and social processes that most likely generated the observed friendship network. Thus, the assumption of ERGMs is that the social network is created through a stochastic process in which friendships are shaped by structural network properties as well as individual attributes (e.g., CHC). Markov chain Monte Carlo maximum likelihood estimation (MCMCMLE) is used to test model parameters. Simulation of a distribution of random graphs is obtained from starting parameter values, and repeated to get refined values by comparing the simulated distribution of graphs to the observed network. MCMCMLE is the current recommended approach (Robins et al., 2007) and the default estimation technique in the "ergm" package.

In the current study, models were estimated for each sample school separately, and then a meta-analysis technique (22) using the 'metafor' package (29) in R Language and Environment for Statistical Computing was conducted in order to combine results. In this method, estimates for each school are used to calculate a semi-weighted sample mean (30) for each effect, in which parameters are weighted inversely by their standard errors, thereby giving more weight to more precise estimates. The standard errors are used to calculate estimates of the sample variance for each effect, and the significance of effects is based on the t-value calculated from each estimated sample mean and variance. A more detailed account of this method can be found in Snijders & Baerveldt, 2003 (21) and Lubbers & Snijders, 2007 (31).

Model Specification and Model Selection Procedures. In order to explicitly model the relationship between CHC and adolescent friendships, several parameters must be tested. CHC *indegree* measures the association between CHC and the likelihood of being nominated as a friend by others. This effect represents the desirability, or popularity, of adolescents with CHC.

A significant and negative coefficient would indicate that adolescents with CHC are socially marginalized. CHC *outdegree* measures the association between CHC and the likelihood of sending out friendship nominations. This effect represents reaching out for friendships, or level of sociability in the network. A significant and negative coefficient would indicate that adolescents with CHC are more socially withdrawn in comparison to adolescents without CHC. Lastly, CHC *nodematch* captures the effect of similarity, or homophily, in CHC on the likelihood of a friendship connection. This effect indicates whether adolescents with CHC are more likely to be friends with other adolescents who also have CHC, and vice versa.

The current study also controls for important demographic variables associated with friendship network structure, including grade level, gender, parental education, depression, and ethnicity. Further, several endogenous features of the network, or structural properties known to increase the likelihood of friendship, were also included as control variables. For example, friendship reciprocity (e.g., mutuality in friendship nominations) and transitivity (e.g., friendship formation based around common others) contribute to the likelihood of friendship ties and were controlled. For all models, goodness of fit diagnostics were tested using AIC and BIC criteria, in addition to visual goodness of fit plots produced by the "ergm" package. In this way, all potential covariates were tested and nested models were compared to determine the best fitting model specification. Through this process, two potential covariates, ethnicity and depression, were excluded from the final model. A complete list of all parameters included in final model, in addition to their interpretation, is provided in Table 1.

Results

Descriptive Statistics.

Table 2 provides descriptive statistics for the sample. Adolescents were evenly split on gender (50.11% female) and across grade level. Only 3% of the sample identified as Hispanic.

All control variables had relatively low rates of missing data (e.g., average of 2.1%); as a result, the school mean or mode was imputed, respectively. Approximately 17% of the sample reported having CHC. Adolescents, on average, received 2.22 friendship nominations and sent out 2.33 nominations. Differences across schools in descriptive statistics were tested using chi-square tests for categorical variables (e.g., gender, parental education), and an ANOVA was used to test for differences in the continuous variables (e.g., average number of friendships). No significant differences were found across the schools with regard to basic demographic variables, demonstrating a highly homogenous sample. Differences were found in the average number of incoming and outgoing friendship ties across schools, a common feature of social networks within schools (8, 32).

Friendship Dynamics.

Results for the final ERGM model are displayed in Table 3. As expected, adolescent friendships demonstrated several endogenous, or structural, features of social networks. Specifically, adolescents showed a tendency toward reciprocated friendships (e.g., mutual effect; $b = 2.70$, $p < .001$) and also transitivity (e.g., geometrically weighted edgewise shared partners and geometrically weighted dyadwise shared partners; $b = 1.29$, $p < .001$, $b = -0.24$, $p < .001$, respectively). For example, adolescents had 14.88 higher odds of reciprocated friendships (i.e., $e^{2.70} = 14.88$) than unilateral friendships. In the current sample, shared demographic features such as gender similarity, grade similarity, and parental education were not significantly associated with the structure of friendship ties.

Moving to the primary variables of interest, three parameters were included to capture the relationship between CHC and adolescent friendship: CHC based marginalization (e.g., CHC indegree), CHC based withdrawal (e.g., CHC outdegree), and friendship based on CHC homophily (e.g., CHC nodematch). In the current sample, no significant evidence was found for

marginalization (p = 0.27), withdrawal (p = 0.90), or homophily (p = 0.72) based on CHC. The lack of significant findings for an association between CHC and adolescent friendship patterns suggests that the social network structure of adolescents with CHC does not differ from that of their peers without CHC.

Discussion

Peer relationships contribute to adolescent wellbeing and healthy development (1, 2), and health indicators, such as obesity (5) and mental health (6) have known associations with adolescent friendship structure. Further, developmental theories (4) postulate a bidirectional relationship between social context and health, such that adolescent friendships and health are interdependent. Previous research suggests that adolescents with CHC experience social isolation (11, 13), but no research to date has examined the extent to which CHC is related to friendship patterns in adolescence. Thus, the current study employed advanced social network methods to measure the social mechanisms linking CHC and adolescent friendship in a sample of six U.S. high schools. Specifically, the study used objective social network measures of network structure to determine if adolescents with CHC were socially marginalized, socially withdrawn, or showed a tendency toward friendships with other adolescents who also have CHC.

With regard to the theoretical variables of interest, the current study did not find evidence that CHC was significantly related to the structure of adolescent friendships. Although previous research has found that adolescents with CHC experience social isolation (11-13), the current study found that the social network structure of adolescents with CHC did not differ from that of their peers without CHC. This difference could be due to the fact that previous research relied on adolescent self-report of isolation from peers, while the present study utilized objective social network measures of friendship connections. Findings from the present study suggest an important distinction between the subjective feelings of social isolation captured in previous

work (11-13), and the current focus on objective quantity of social connections. Thus, future research would benefit from simultaneously examining subjective feelings of social isolation alongside objective measures of social network structure, in order to provide a more nuanced picture of the social lives of adolescents with CHC.

In addition to the theoretical variables of interest, the current study controlled for a number of alternative mechanisms known to be related to adolescent friendship structure. Consistent with previous research (21, 9), adolescent friendships followed basic endogenous, or structural, properties of social networks. For example, friendships were reciprocated (e.g., mutual effect) and associated with common others (e.g., geometrically weighted edgewise shared partner, geometrically weighted dyadwise shared partner). In the current sample, similarity in gender, grade, and parental education was not significantly related to the likelihood of friendship. Further, baseline measures of sociability (e.g., geometrically weighted outdegree) and popularity (e.g., geometrically weighted indegree) were not significant, suggesting comparability among adolescents in sending and receiving friendship nominations.

Overall, the present study adds to the literature on adolescent development by examining the structure of adolescent social networks in relation to CHC and highlighting the objective comparability of friendship structure between adolescents with CHC and adolescents without CHC. The results of this study, in light of previous work (11-13), suggest two practical focus areas for future research. First, a concurrent investigation of social network data and feelings of social isolation would offer insight into the potential differential impact of CHC on adolescent objective (i.e., quantity of social connections) and subjective (i.e., reported social isolation) social well-being. Secondly, an analysis of longitudinal data on CHC and friendships is needed in order to explore the dynamic nature of social connections, particularly with regard to how CHC predicts changes in adolescent friendships over time.

Limitations and Conclusions

Several limitations of the current study need to be mentioned. Most notably, the study is limited to six schools within Add Health, each with a relatively small sample size. The sample is limited by available CHC data within the Add Health dataset and computational challenges associated with the use of ERGMs on large social networks (20, 26). As a result, the findings generalize to schools of similar size, and differences in the generative mechanisms behind adolescent friendship connections may be present in larger schools. In addition, CHC is measured through parental report on three common CHC, and therefore does not necessarily reflect medically diagnosed conditions. The measure of CHC also neglects to include aspects of condition severity, which likely impact the extent to which the CHC has social implications. More detailed measurement of CHC is needed in future data collection efforts. Lastly, the study is cross-sectional in nature, and although the design allowed for the current research questions to be adequately examined, the design has practical limitations. Longitudinal data would allow for dynamic friend selection processes to be explored, as well as increases or decreases in social isolation over time.

Despite these limitations, the current study serves as a first step toward exploring the social networks of adolescents with CHC. Building upon previous literature that highlighted the negative social consequences of CHC (11-13), the main goal of the present study was to determine if the social network structure of adolescents with CHC differs from that of their peers without CHC. Specifically, the study investigated the relationship between CHC and social marginalization and social withdrawal, in addition to homophily, or similarity in CHC status. Results demonstrate that CHC had no bearing on the social structure of adolescent friendships, thus suggesting that CHC are not associated with objective measures of social connections during adolescence.

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Table 1
Interpretation of Parameters in Final Models

Parameter	Interpretation
Endogenous network properties	
Edges	Baseline number of ties within the network
Mutual	Likelihood of reciprocated friendship
Geometrically weighted edgewise shared partner	Likelihood of friendship based on the number of friendship partners linking two individuals
Geometrically weighted dyadwise shared partner	Likelihood of individuals without a friendship sharing multiple friendship partners
Geometrically weighted indegree	Tendency for some individuals to receive many nominations (e.g., popularity)
Geometrically weighted outdegree	Tendency for some individuals to send many nominations (e.g., sociability)
Basic covariates	
Gender similarity	Likelihood of friendships between individuals of the same biological sex
Grade similarity	Likelihood of friendship between individuals in the same grade
Parental education similarity	Likelihood of friendship between individuals with similar parental education
Chronic health conditions (CHC) effects	
CHC indegree (marginalization)	Difference in the likelihood of receiving friendship nominations based on whether the individual has CHC
CHC outdegree (withdrawal)	Difference in the likelihood of nominating friends based on whether the individual has CHC
CHC nodematch (homophily/similarity)	Likelihood of friendship based on whether both friendship sender and receiver have CHC

Note: Parameters represent only the effects included in the final model after following model fitting procedures. Hispanic ethnicity and depression, for example, were tested, but are excluded from the final model.

Table 2.
Descriptive Statistics of the Sample

Characteristic	Percent	P-Value
Female	50.11%	0.68
Hispanic	3.04%	0.98
Grade		0.94
9	25.16%	
10	25.60%	
11	26.68%	
12	22.56%	
Parental education		0.99
1 Less than high school	9.98%	
2 High school	33.84%	
3 Some college	27.55%	
4 College degree	18.00%	
Depression		0.98
1 Low	85.90%	
2 Moderate	14.10%	
3 High	0.00%	
Chronic health conditions		0.94
0 No CHC	71.37%	
1 CHC	17.57%	
Missing	11.06%	
Friendship network		
Average number of incoming friendships, mean (SD)	2.22 (1.89)	<.001
Average number of outgoing friendships, mean (SD)	2.328(2.085)	<.001

Note. $N = 461$

P-Values represent chi-square tests for categorical variables. The average number of friends is calculated within the statnet package and between school differences tested with a one-way ANOVA.

Table 3.
Parameter Estimates from Final Model.

Parameter	Coefficient (SE)	Between School Difference P-Value
Edges	-2.70 (0.15) ***	0.08
Mutual	2.51 (0.15) ***	0.28
Geometrically-weighted edgewise shared partner	1.29 (0.07) ***	<.01
Geometrically-weighted dyadwise shared partner	-0.24 (0.02) ***	0.24
Geometrically-weighted indegree	-0.68 (0.15) ***	0.29
Geometrically-weighted outdegree	-0.80 (0.15) ***	0.54
Gender similarity	0.01 (0.06)	0.05
Grade similarity	-0.04 (0.03)	0.65
Parental education similarity	0.05 (0.03)	0.49
CHC indegree	0.10 (0.08)	0.10
CHC outdegree	0.01 (0.08)	0.44
CHC similarity	-0.03 (0.08)	0.09

Note. *** $p < 0.001$, **$p < 0.01$, * $p < 0.05$.