Research Article

Using social network analysis to examine alcohol use among adults: A systematic review

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Abstract

Background

Alcohol use and abuse constitute a major public health problem and identifying their determinants is a priority. Social network analysis can indicate how characteristics of social networks are related to individual health behaviors. A growing number of studies have used social network analysis to examine how social network characteristics influence adult alcohol consumption, but this literature has never been systematically reviewed and summarized. The current paper systematically reviews empirical studies that used social network analysis to assess the influence of social network characteristics on drinking behaviors in adults.

Methods

A literature search of PubMed/MEDLINE, EMBASE, PsycINFO and Web of Science databases and a review of the reference lists of retrieved articles was conducted in March 2019. Two reviewers independently screened 5,510 non-duplicate records, and further screened the full text of 150 articles to determine their eligibility for inclusion. Seventeen articles were judged eligible and included.

Results

Most studies were conducted among young adults (mean age<30), in university settings or follow up visits with adolescent networks moving into adulthood. The objectives and methods of the included studies were heterogeneous. All included studies reported a statistically significant association between a social network characteristic and an alcohol consumption-
related outcome. Social network members drinking behaviors were associated with participants’ drinking behaviors in multiple ways.

Discussion
In young adults, among whom the majority of identified studies were conducted, with whom they socialize and how they socialize appears to be associated with alcohol consumption; this was observed across methodologies and settings. We still know very little about the relationship of social networks to drinking in older age groups, and in populations most impacted by alcohol. As social networks appear to play a role in the consumption of alcohol in young adulthood, interventions that utilize social networks to help reduce harmful alcohol consumption should be considered.

Introduction
Alcohol consumption is prevalent worldwide, with more than 2.4 billion people (33% of the global population) being current drinkers [1]. In the US, the prevalence of two forms of excessive alcohol consumption, high-risk drinking and alcohol use disorder, have increased substantially in adults over the past decade, such that 1 in every 8 adults report past-year high-risk drinking [2] and the prevalence of lifetime alcohol use disorder is high [3]. Alcohol use is also a leading cause of global disease burden and health loss [1]. Risk of all-cause mortality is positively associated with level of alcohol consumption, such that any level of consumption is potentially harmful [1]. These recent findings are consistent with the well-demonstrated relationship of excessive alcohol consumption to numerous adverse health consequences [2–5], and to increased morbidity and mortality worldwide [6–8]. Excessive alcohol consumption additionally places psychological and financial burdens not only on those who engage in these behaviors, but also their families, friends, coworkers and society as a whole [9, 10].

Many studies have identified individual-level determinants of alcohol consumption [2, 3, 11], but these studies have limited their focus to psychological or other individual characteristics of alcohol users. Socio-ecological models [12] point to larger social units, ranging from networks to institutional factors, as potential drivers of alcohol use. In this regard, one step beyond looking at individual risk factors is to consider the influence of social networks on alcohol-related outcomes. Social network analysis can be used to show how peer drinking behavior and patterns of relationships that connect social actors influence an individuals drinking behavior. That alcohol consumption can both influence choice of relationships (e.g. selecting drinking buddies as friends) and be influenced by them (e.g. being pressured by peers to drink alcohol), suggests that this is an area ripe for investigation.

Social network analysis is the term applied to a set of theories and methods used to study social interactions between individuals, and how these social interactions influence various outcomes [13]. A fundamental tenet in social network analysis is that it incorporates information about relationships between members of a shared social network. The most comprehensive approach that researchers use to collect data on social networks is termed a sociometric network approach, which involves interviewing multiple members (ideally all members) of a social network [13]. When a social network of interest is complete (i.e. bounded), rosters can be used to facilitate selecting the sampling frame and identifying connections between social network members. Alternatively, social network data can be collected by interviewing an
individual (i.e. an index) and then interviewing the social network members that an individual nominates (i.e. alters). This process can be carried out successively, for as many waves as are needed until saturation of network members and the ties between them are achieved [14]. In the case that a complete network is not sampled, collecting data among multiple members of a social network at least allows for the creation of directed graphs, where there can be directionality in the relationships among members of a shared social network. These approaches allow one to measure the actual behavior of shared social network members, rather than just an individual’s perception of shared social network members’ behavior, which is known to be differentially biased (i.e. they tend to reflect the behaviors of the individuals describing them) [13, 15]. Social network data, both sociometric and that limited to directed graphs, provide a global view of a social network and its structure, including multiple members’ perspectives, and thus they have great analytic possibilities. This approach has been effectively used in schools, for example, as networks are characterized at the classroom level and diffusion of behaviors measured and intervened upon [16–18].

The relevance of social networks to communicable diseases that require the spread of pathogens between people is obvious [19–25]. Social networks have also been shown to influence non-communicable diseases [26, 27], and health-related behaviors [28–35]; both unhealthy behaviors, such as drug use and specific HIV related behaviors [36–38], and healthy behaviors, such as smoking cessation or HIV prevention [39–43]. Specific interventions have also been developed that utilize social networks to promote behavior change [44]. One way that social networks have been shown to influence the health of their members is that the characteristics of the people in one’s social network provide a context for one’s own behavior and norms. Members of a shared social network might influence each other through persuasion, sharing information or expressing support. In order to study these peer effects, the characteristics of social networks members can be measured to assess their relationships to the characteristics of other members in a shared social network (e.g., is an individual’s alcohol use associated with the alcohol use of one’s friends). [45–48]. Another way to look at peer effects is by looking at the distribution of a characteristic throughout a social network; if a characteristic is not randomly distributed then there is said to be clustering, and a network is said to be homophilic on that characteristic. Homophily can either be a result of confounding (peers are similar because of a shared environment), selection (i.e. individuals become friends with others who are like them), or socialization/induction (friends influence each other to become more similar). Selection and socialization are the mechanisms for peer influence; attempting to identify and isolate their effects is the theoretical and empirical basis for using social network analysis.

Social network structure has also been found to be an important driver of health behaviors [49, 50]. These structures can include network positions (central, bridging), sub-network groupings (i.e. faction, clique) and cohesion among others [51]. For example, social network ties (i.e. relationships), in themselves, can be considered as potential determinants of health (e.g. is a member of a social network well connected or fairly isolated) [52–54]. Also, the total size of one’s social network can matter or whether a network is densely or loosely connected. An individual’s position within a network can also matter, as it might reflect their level of prestige within that group or they play a critical role in terms of transmission. These means of influence can be inter-related; as for example, one’s degree of connectedness to a specific social network is positively associated with one’s likelihood of reflecting the normative behavior of that group [52].

Empirical research studies have used social network analysis to examine alcohol-related outcomes, although these have mostly been conducted among adolescent populations [28–35, 55, 56]. A systematic review on the use of social network analyses to understand risky behaviors focused solely on studies of adolescents [57], and only included studies that used data
from the National Longitudinal Study of Adolescent to Adult Health (Add Health) [58]. This review identified eight studies that looked at alcohol-related outcomes, all of which found that adolescent friendship networks promoted drinking alcohol [57]. Various types of friendships were found to influence adolescents’ drinking behavior, with friendships that mattered (based on levels of closeness or by being reciprocated), being more likely to exert influence. The included studies that used longitudinal data showed that individuals who have friends who drink or are linked to friendship networks where individuals drink are at increased risk for drinking themselves, initially and over time.

How social networks influence drinking behaviors could be substantially different among adults compared to adolescents [59]. For example, peer groups tend to expand and diversify from adolescence into adulthood [60]. Not only does one’s peer group change, but so does the amount of time one spends with peers and how one interacts with them [61]. Perhaps, as a result, the influence of peers is believed to wane in later adulthood [62]. Looking at things beyond homophily, the impact of social network structure on alcohol might also be qualitatively different in adults compared to adolescents. For example, centrality is the most common social network analysis measure used in alcohol research among adolescents, and we know that more popular adolescents (i.e., those with more friends) have higher levels of alcohol use [57]. However, in adulthood, having more friends may lose its association with alcohol use as it becomes less important in reflecting perceived social norms. Also, centrality may operate differently in adolescents and in adults above the legal drinking age as such adults would not need to rely on peers to access alcohol. Individual studies have examined the relationship of social networks to alcohol use among adults. However, thus far, this literature has not yet been summarized in a systematic review. The lack of a review on this topic in adults represents an important gap in knowledge. The current paper aims to fill this gap by systematically identifying and describing empirical studies that used social network analysis to evaluate alcohol-related outcomes among adults (persons who are 18 years and older). We then synthesize the findings of the identified studies that statistically measured the influences of social network characteristics on alcohol use in adults.

Methods

This review was informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement. The PRISMA checklist [63, 64] is shown in S1 Table.

Data sources and literature search

A literature search of 4 databases (PubMed/MEDLINE, EMBASE, PsycINFO and Web of Science, Sociological) was conducted in March 2019 to identify studies that used social network analysis to evaluate the effects of social network characteristics on alcohol use. Keyword and terms used in search strategies varied based on the database to account for distinct indexing criteria and are described in detail in S2 Table. To identify additional studies not found in the literature search, the reference lists of relevant review articles of social network analysis [13, 44, 57] and included articles were reviewed. The literature search was conducted with guidance from an Education and Curriculum Librarian who serves as the Coordinator for Systematic Review Services at the New York University School of Medicine.

Screening

Duplicates were removed and screening of retrieved articles by title and abstract was conducted by two independent reviewers using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Final inclusion
was determined by two independent reviewers (JK & EG) screening the full-text of potentially eligible articles using the following criteria. Studies were eligible to be included in the review if they (1) were published in a peer-reviewed journal, (2) were written in English, (3) were conducted in human populations, (4) utilized a social network analysis design that included directed graphs (where there is directionality in the ties) and which data were collected beyond dyadic pairs (i.e., data linking participants were measured or inferred (e.g., known roommates were considered to be connected) and data were collected among alters for 3 or more connected individuals) and network measures were calculated based on this data, (5) evaluated an alcohol-related outcome, and 6) included a majority of participants that were adults (18 years or older). Studies were excluded if (1) the impact of social networks was assessed using simulations, (2) the study described qualitative research or was a case study. In the few cases on which opinions about inclusion differed, the reviewers met and reached consensus through discussion.

Quality assessment
We used a 12-item quality assessment tool (S3 Table) to evaluate study relevance and methodology. This tool was developed using modified sets of criteria from other quality assessment tools for assessing observational studies [65] and network studies [66]. The tool assessed description of: the research question, data collection procedures (data source(s), study setting, sample size, response rate, sample selection), measures used (exposure and outcomes), analysis of social network data, results and findings, strengths and limitations, and conclusions drawn.

Data extraction and synthesis
A data extraction form was developed to extract information on study objectives, study design and sampling approach, data collection method, setting and target population, participants, social network data collection procedures, outcome measurement, social network analysis methods used to analyze the data and calculated measures, statistical analyses used (as relevant to social network analysis), and key findings.

Results
Identifying empirical studies
The literature search yielded 5,907 records for screening (5,477 after removing duplicates), and an additional 33 were included based on reference list review for a total of 5,510. The full text of 150 articles was reviewed to determine eligibility and 17 articles were judged potentially eligible and further assessed for quality and relevance (S4 Table). Scores on the quality assessment tool scale ranged from 78%-100% (mean = 95%). Based on these scores, all 17 articles were included in the review (Fig 1) [67–83]. Because the methodologies used in the included studies were heterogeneous, they did not lend themselves to meta-analysis. Therefore, a narrative synthesis of the studies will be conducted.

Population and setting
Among the included studies, 13 were conducted in the United States [67–70, 72, 73, 75, 76, 78, 79, 81–83], 3 were conducted in Europe [71, 77, 80] and one was conducted in Africa [74]. Most studies (n = 15) were conducted among young adults [67–74, 76–81, 83], the majority (n = 12) of which were among university students [67–71, 73, 76–81]. Five studies were conducted in community settings [72, 74, 75, 82, 83]. Mean age of the participants ranged from 18
years to 51 years. Proportion of male participants ranged from 25% [81] to 100% [71, 74]. Characteristics of the included studies are summarized in Table 1.

### Sampling and study design

Sample selection procedures included the use of respondent-driven sampling, recruitment of peer groups, and the collection of complete sociometric social networks. The studies that used more robust sociometric social network sampling procedures [67–72, 77, 78, 81, 82] either collected data on complete (i.e. bounded) networks [77, 81] or used complete rosters but limited the number of peers that an individual was able to nominate [67–69, 71]. Two of the studies relied on peer nominations or recruitment without the availability of rosters [72, 74, 82]. Sample sizes ranged from 34 [81] to 12,067 [82]. Of the studies, 11 used cross-sectional data [67–70, 72–74, 77–80, 83], 5 used a longitudinal study design [71, 75, 76, 81, 82], and one was a

| Characteristic                                      | n (%)   |
|----------------------------------------------------|---------|
| **Country**                                        |         |
| US                                                 | 13 (76) |
| Europe (Germany, Belgium, Netherlands)             | 3 (18)  |
| Africa (South Africa)                              | 1 (6)   |
| **Setting**                                        |         |
| University                                         | 12 (71) |
| Community                                          | 5 (29)  |

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| Study | Objective | Study details | Study design | Data sources | Social network measure(s) | Statistical analyses | Major findings related to the social network analyses |
|-------|-----------|---------------|--------------|--------------|---------------------------|---------------------|--------------------------------------------------|
| Barnett et al. (2014a) [67] | Investigate five different social network characteristics (indegree centrality, betweenness centrality, outdegree, indegree reciprocity, and outdegree reciprocity) for alcohol use and alcohol-related problems in a college residence network | US; 129 students living on a college campus in the NE; 48% male | Cross-sectional | Interview with SNQ of up to 10 people who lived in the residence hall | Indegree centrality, betweenness centrality, outdegree, indegree reciprocity, outdegree reciprocity | Simultaneous autoregressive (SAR) autocorrelation models | Two network characteristics were significantly associated with alcohol use and a third showed an association for women only. Outdegree was significantly positively related to number of heavy drinking days. Betweenness centrality was significantly positively related to number of alcohol problems. Betweenness centrality and indegree reciprocity were significantly associated with greater alcohol problems for women. |
| Barnett et al. (2014b) [68] | Use a college residence hall peer network to examine associations between peer behaviors and alcohol use, marijuana use, and exercise behavior | US; 129 students living on a college campus in the NE; 48% male | Cross-sectional | Interview with SNQ of up to 10 people who lived in the residence hall | Cluster identification based on betweenness, weekly volume of alcohol consumed by direct ties | Network autocorrelation models | Community detection cluster analysis used only directed ties to detect subcommunities of individuals, and the comparison of those groups established that they differed significantly on demographic, activity, and behavior profiles, including alcohol use and alcohol-related problems. The drinking volume of nominated peers was significantly positively associated with participant drinking volume. |

(Continued)
| Study | Objective | Study details\(^1\) | Study design | Data sources | Social network measure(s) | Statistical analyses\(^2\) | Major findings related to the social network analyses |
|-------|-----------|---------------------|--------------|--------------|--------------------------|--------------------------|---------------------------------------------------------------|
| DiGuiseppi et al. (2018a) \[69\] | Investigate the association between actual and perceived peer drinking and participant drinking, and the possible moderating effect of resistance to peer influence | US; 1342 students enrolled in their first semester at a mid-sized, private university in the NE; 18.7 years = mean age; 45% male | Cross-sectional | All students in the class were included in the social network, participants were asked to select their social network connections from a list of all students. | Binge drinking frequency of important peers | Two separate network autocorrelation models were conducted, one for perceived peer drinking and one for actual peer drinking | Participant’s binge drinking frequency was positively associated with both perceived and actual norms. Resistance to peer influence weakened the effect of perceived peer binge drinking on participant binge drinking, but did not interact with actual norms. |
| DiGuiseppi et al. (2018b) \[70\] | Investigate the association between social network characteristics, alcohol use, and alcohol-related consequences among first-year college students at one university | US; 1342 students enrolled in their first semester at a mid-sized, private university in the NE; 18.7 years = mean age; 45% male | Cross-sectional | All students in the class were included in the social network, participants were asked to select their social network connections from a list of all students. | Indegree (popularity), outdegree (expansiveness), reciprocity, density (the proportion of completed triads, out of all possible triads, among participants' peer nominations), binge drinking norms (average binge drinking frequency among all of the peers that participants nominated) | Four network autocorrelation models were conducted, using the following outcome variables: (1) average number of drinks per week, (2) heavy drinking frequency, (3) alcohol-related consequences, and (4) alcohol-related consequences after controlling for drinks per week. | Popularity (i.e., indegree) and descriptive norms showed significant positive associations with average number of drinks per week, heavy drinking frequency, and alcohol-related consequences and remained significantly associated with alcohol-related consequences even after controlling for alcohol consumption. |
| Giese et al. (2017) \[71\] | Explore the role of friendship reciprocity in shaping frequency and quantity of alcohol consumption among university Freshmen | Germany; 57 first semester psychology students at the University of Konstanz from 2008–2009; 20.9 years = mean age (at baseline); 25% male | Longitudinal | Interview with SNQ that asked participants to nominate the 3 people that they liked most that week from the full list of participants | Outdegree nominations and indegree nominations | Multilevel regression models | Participants’ frequency of drinking was associated with reciprocating friends’ frequency of drinking. Participants’ quantity of drinking was associated with friends’ quantity of drinking regardless of reciprocation. |
Table 2. (Continued)

| Study                     | Objective                                                                 | Study details | Study design | Data sources                     | Social network measure(s) | Statistical analyses^2 Major findings related to the social network analyses |
|---------------------------|---------------------------------------------------------------------------|---------------|--------------|----------------------------------|---------------------------|-----------------------------------------------------------------------------|
| Janulis et al. (2015) [72] | Examine relationships between network (i.e., transitivity and network size), dyadic (e.g., age difference), and individual characteristics and drug and alcohol behavior with substance use alters to better understand the social and contextual factors associated with substance use behavior among young MSM | US; 156 young MSM; 20.1 years = mean age (at baseline); 100% male | Cross-sectional | Individual interviews and RDS recruitment data | Transitivity, network size, dyadic frequency and type of drug use | Logistic mixed models with random intercepts A participant’s drug use and a participant’s frequency of drug and alcohol use with substance use alters were positively associated with the network transitivity of their substance use network. Thus, the ties between alters that an individual uses substances with is related to the type and frequency of substance use with those alters. |
| Kenney et al. (2017) [73] | Examined how misperceptions of residence hall peers, both overall using a global question and those designated as important peers using person-specific questions, were related to students’ personal drinking behaviors | US; 108 students living on a college campus in the NE; 49% male | Cross-sectional | Interview with SNQ of up to 10 people who lived in the residence hall | Self-reported and peer-reported alcohol consumption | Network autocorrelation models Participants accurately perceived the drinking of nominated friends but overestimated the drinking of residential peers. Misperceptions of peer drinking predicted personal drinking behavior. |
| Knox et al. (2017) [74]   | describe alcohol use among black South African MSM and identify determinants that put them at risk for hazardous drinking | South Africa; 480 MSM living in Pretoria and the surrounding townships; 24 years = mean age; 100% male | Cross-sectional | Individual interviews and RDS recruitment data | outdegree centrality, proportion of a participant’s ties that screened positive as hazardous drinkers using the AUDIT-C | Multivariable logistic regression Men whose social networks included a higher proportion of hazardous drinkers were more likely to be hazardous drinkers themselves. |
| Latkin et al. (1996) [75] | Examine the prospective association between baseline self-reported drug and alcohol use of the network members of injection drug users, and self-reported sexual behaviors and alcohol use at 5-month follow-up | US; 71 nontreatment inner-city injection drug users who volunteered for a network-oriented HIV preventive intervention and 227 members of their drug networks from 1991–1992; 38 years = mean age; 85% male | Longitudinal | Detailed, face-to-face interview on background, HIV-related behaviors in the prior 6 months, and SNQ where they were required to provide names and descriptive information on their network members. Indexes were compensated $25 for each drug-sharing network member that came in to be interviewed. | Drug networks’ mean baseline level of alcohol consumption | Prospective multiple logistic regression Drug networks’ mean baseline level of alcohol consumption was a significant predictor of indexes’ daily alcohol consumption in the prior six months. |
Table 2. (Continued)

| Study                  | Objective                                                                 | Study details¹ | Study design | Data sources | Social network measure(s) | Statistical analyses² | Major findings related to the social network analyses |
|------------------------|---------------------------------------------------------------------------|----------------|--------------|--------------|---------------------------|-----------------------|-------------------------------------------------------|
| Lau et al. (1990) [76] | Explore sources of stability and change in young adults' beliefs and behavior concerning drinking during the first 3 years of college | US; 947 students admitted to Carnegie Mellon University and their parents; 69% male; 18 years = mean age (at baseline) | Longitudinal Interviews among participants, their parents and up to 2 other participants in the study-roommates and people named by the youths as their best friends at college. | Parents' alcohol beliefs, parents' alcohol consumption, peers' alcohol beliefs, peers' alcohol consumption, | Structural equations analysis with latent variables | Parental influence on their children’s drinking beliefs and drinking behavior are present at baseline and persist, despite weakening, at least through the college years. Peers drinking behavior was associated with participant’s drinking behavior. |
| Lorant et al. (2015) [77] | Analyze the role of peers and of social position within a university network in drinking behavior | Belgium; 487 undergraduates in 2 faculties (Engineering and Psychology) in a university in 2010; 45% male | Cross-sectional Paper-pencil questionnaires with SNQ where participants were provided with a complete list of all students to identify those with whom they had the following relationships: friends, roommates, studying or working with, and spending leisure time with. | In-degree, closeness, cross-gender relationships, effective size | Poisson regression with permutation tests to assess the distribution of the estimates. | Being socially close to binge drinkers was associated with a higher frequency of binge drinking; higher for reciprocated ties than non-reciprocated. The risk of binge drinking increased with centrality but decreased with social capital. Having cross-gender relationships decreased the risk of binge drinking. The effect of centrality and gender on binge drinking depends on the composition of the network. |
| Meisel et al. (2018) [78] | Investigate the network of social connections between drinkers on their heaviest drinking occasions | US; 972 students enrolled in their first semester at a mid-sized, private university in the NE who reported past-month drinking; 18.7 years = mean age; 45% male | Cross-sectional All students in the class were included in the social network, participants were asked to select their social network connections from a list of all students. Participants who self-reported drinking in the past 30 days were additionally asked to indicate which of the people named in their sociocentric network were there. | Maximum drinking day: indegree, outdegree, betweenness centrality, mutuality, and ego density | Network autocorrelation models were conducted to examine if network indices were associated with the participant’s maximum number of drinks. | The total number of times a participant was nominated as being present on another students’ heaviest drinking occasion (i.e., maximum drinking day indegree) and the number of drinks consumed by the participant’s nominated ties on the ties’ maximum drinking days both independently were associated with a participant’s maximum number of drinks. |
Table 2. (Continued)

| Study | Objective | Study details | Study design | Data sources | Social network measure(s) | Statistical analyses | Major findings related to the social network analyses |
|-------|-----------|---------------|--------------|--------------|---------------------------|----------------------|---------------------------------------------------|
| Ott et al. (2016) [79] | Learn about the unknown average number of alcoholic drinks consumed on drinking days and the association between certain personal characteristics and alcohol consumption | US; 125 students living on a college campus in the NE who nominated other network members or who were nominated by other network members; 47% male | Cross-sectional | Interview with SNQ of up to 10 people who lived in the residence hall | Self-reported and peer-reported alcohol consumption | Novel Bayesian comparative calibration model that uses covariate information to characterize the joint distribution of both self and peer-reports on the network for estimating discrepancies in network surveys, then applied to the data for full Bayesian inference. | Use of peer-reports improves estimates of self-reported alcohol consumption. Peer-reports of alcohol consumption are overestimates. Men tended to have larger discrepancies than women. |
| Overbeek et al. (2010) [80] | Assess the relative importance of best friends’ alcohol use versus general levels of alcohol use in the peer setting for predicting young adults’ alcohol use | Netherlands; 221 young adults in 28 peer groups; 46% male majority groups | Naturalistic observation study | 10-minute questionnaire followed by 2 hours observed drinking in a bar-lab | Peers’ quantity of alcohol consumption during the observation period | Multilevel regression analysis using both fixed and random effects | Average peer group levels of alcohol consumption was the strongest predictor of youths’ alcohol consumption in an experimental setting. This finding was less pronounced for females. |
| Phua (2011) [81] | Examine the influence of popularity and conforming to perceived peer norms on smoking and drinking among college fraternity members using social network analysis | US; college fraternity at private university in SW; 34 freshmen pledges; 20.1 years = mean age (at time period 1); 100% male | Longitudinal | Interview with SNQ of other fraternity members | Homophil, popularity (indegree nominations) | ANOVA density models; Quadratic Assignment Procedure correlation analyses | The network became more homophilous with regards to drinking. Popularity in the fraternity network significantly predicts heavier drinking (i.e. he more popular a member the more likely he is to be a heavier drinker). (Continued) |
Table 2. (Continued)

| Study                  | Objective                                                                 | Study details ¹                                          | Study design   | Data sources                                                                                                                                  | Social network measure(s)                                  | Statistical analyses²                                                                 | Major findings related to the social network analyses                                                                 |
|------------------------|---------------------------------------------------------------------------|----------------------------------------------------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Rosenquist et al. (2010) [82] | Explore quantitatively whether alcohol consumption behavior spreads from person to person in a large social network of friends, coworkers, siblings, spouses, and neighbors, followed for 32 years. | US; The Framingham Heart Study; 12,067 persons assessed at several time points between 1971–2003; 50.9 years = mean age; 48% male | Longitudinal   | Participant data, collected every 2 to 4 years, includes physical examinations, laboratory tests, noninvasive cardiac and vascular testing, battery testing. questionnaire results, demographic information, and SNQ self-described social ties, collected in each of the 7 waves of the study. | Alcohol consumption of social network ties at various degrees of separation. Clustering in alcohol consumption (homophily, confounding, induction) | Longitudinal logistic regression models using GEE to account for multiple observations. Observed clustering of alcohol consumption within the network compared with 1000 simulated networks with same topology and prevalence of drinking as the observed network, but with the incidence of drinking randomly distributed across members. | Participants are 50% more likely to drink heavily if a person they are directly connected drinks heavily. The size of the effect is 36% for people at 2 degrees of separation and 15% for people at 3 degrees of separation. The effect disappears at 4 degrees of separation. Each heavy drinker in a participant’s social network increased the likelihood of drinking heavily by 18% and decreased the likelihood of abstinence by 7% but had no effect on moderate alcohol consumption behavior. Female contacts are significantly more likely than male contacts to influence the spread of heavy alcohol consumption. |

(Continued)
naturalistic observation study in a 'bar-lab' [80]. Details of the individual studies, including objectives, study period and design, setting, participant characteristics, data sources, social network measures, analytic methods, and major findings are presented in Table 2.

Table 2. (Continued)

| Study            | Objective                                                                 | Study details                                      | Study design          | Data sources                                      | Social network measure(s) | Statistical analyses² | Major findings related to the social network analyses |
|------------------|---------------------------------------------------------------------------|---------------------------------------------------|-----------------------|--------------------------------------------------|---------------------------|-----------------------|-----------------------------------------------------|
| Tucker et al. (2015) [83] | Investigated whether substance use among emerging adults living in disadvantaged urban areas was influenced by peer and family social network messages that variously encouraged and discouraged substance use. | US, Birmingham, Alabama; 344 residents of lower income neighborhoods recruited via RDS; 18.9 years = mean age; 68% female | Cross-sectional       | Individual 1.5-hour interviews and RDS recruitment data | Peer substance users in participants' immediate social networks | Linear regression | Substance use (alcohol and other drugs) by close network members was associated with global substance involvement but not alcohol involvement, specifically. |

¹Participant age and sex and study dates are included if it was reported in the article
²Includes statistical tests that specifically incorporated network measures

Abbreviations

SNA = social network analysis; SNQ = social network questionnaire; RDS = Respondent driven sampling; MSM = men who have sex with men

Definitions

Nodes: Distinct members of a social network (e.g., study participants)
Ego: An individual focal node providing information about their social network
Alter: The nodes to whom an ego is directly connected
Ties (edges): Representations of relationships (connections) that link nodes within a network
Structure: Networked sets of nodes and the ties that connect them
Characteristic: A feature or quality belonging to a node
Indegrees/in degree centrality: The number of alters that nominate a given ego
Indegree centrality: How often an individual falls on the shortest relationship path between two other individuals in the network; reflects the extent to which an individual mediates other relationships
Outdegree/out degree centrality: The number of people an individual selects/nominates within the network
Reciprocity: Whether social network members mutually nominate each other, can be applied to both indegree and outdegree nominations
Mutuality: the extent to which social network members nominate each other, calculated by dividing the number of reciprocated ties by the total number of unreciprocated ties plus the total number of reciprocated ties.
Ego density: the total number of ties between an ego’s nominations divided by the total number of possible ties between the nominations
Prestige: How many connections an ego has and how many connections the alters of the ego has, and so on
Group integration: The extent to which an ego’s outdegree nominations are in a bounded social network (e.g. a school), including within sub-networks (e.g. grades)
Network density: The total number of observed connections divided by the maximum number of possible connections
Transitivity: The extent to which the relation between two members in a shared social network that are connected by another member is transitive, or put more plainly, that friends of a person’s friends are also his friends
Closeness: The minimum number of ties needed to reach all the other individuals in the network
Gender heterophily: An index of how many cross-gender relationships an ego nominates
Effective size: The number of alters that ego has, minus the average number of ties that each alter has to other alters
Cluster identification: Identifying clusters within a network by progressively deleting the edges with the highest edge betweenness
Homophily: The tendency for members of a shared social network to share similar characteristics

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Objectives

An objective of all the included studies was to assess how a social network characteristic was associated with alcohol consumption. Specifically, 12 studies assessed the association between characteristics of network members (e.g. peers’ weekly alcohol consumption or peers’ beliefs about alcohol) and alcohol consumption [68, 70, 71, 73–76, 78–80, 82, 83]. Eight studies assessed the association between characteristics of network structure, such as network size, network shape, network attributes, or position within a network, and alcohol consumption [67–69, 72, 77, 78, 81, 82].

Measures

The measures used in the included studies were heterogeneous. Table 3 provides definitions for the social network characteristics that the studies examined, which included: attributes of network members (e.g. peers’ weekly alcohol consumption or peers’ beliefs about alcohol), indegree/indegree centrality, betweenness centrality, outdegree/outdegree centrality,

Table 3. Social network measures used in the identified studies and their definitions.

| Social network measure         | Definition                                                                 |
|-------------------------------|-----------------------------------------------------------------------------|
| Indegree/indegree centrality  | The number of alters that nominate a given ego                               |
| Betweenness centrality        | How often an individual falls on the shortest relationship path between two other individuals in the network; reflects the extent to which an individual mediates other relationships |
| Outdegree/outdegree centrality| The number of people an individual selects/nominates within the network      |
| Reciprocity                   | Whether social network members mutually nominate each other, can be applied to both indegree and outdegree nominations |
| Prestige                      | How many connections an ego has and how many connections the alters of the ego has, and so on |
| Group integration             | The extent to which an ego’s outdegree nominations are in a bounded social network (e.g. a school), including within sub-networks (e.g. grades) |
| Network density               | The total number of observed connections divided by the maximum number of possible connections |
| Transitivity                  | The extent to which the relation between two members in a shared social network that are connected by another member is transitive, or put more plainly, that friends of a person’s friends are also his friends |
| Closeness                     | The minimum number of ties needed to reach all the other individuals in the network |
| Gender heterophily            | An index of how many cross-gender relationships an ego nominates             |
| Effective size                | The number of alters that ego has, minus the average number of ties that each alter has to other alters |
| Cluster identification        | Identifying clusters within a network by progressively deleting the edges with the highest edge betweenness |
| Homophily                     | The tendency for members of a shared social network to share similar characteristics |

Definitions

Nodes: Distinct members of a social network (e.g., study participants)
Ego: An individual focal node providing information about their social network
Alter: The nodes to whom an ego is directly connected
Ties (edges): Representations of relationships (connections) that link nodes within a network
Structure: Networked sets of nodes and the ties that connect them
Characteristic: A feature or quality belonging to a node

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reciprocity, prestige, group integration, density, transitivity, closeness, gender heterophily, effective size, cluster identification, and homophily.

All the studies measured some form of alcohol consumption over a specific time period as the outcome. These included frequency of alcohol consumption, quantity of alcohol consumption, and frequency of binge drinking. Some studies used a single item to measure alcohol consumption, while others measured multiple forms of alcohol consumption using previously validated scales. One study looked at frequency of drug and/or alcohol use with a social network member in the past 6 months without distinguishing between drug and alcohol use [72]. The naturalistic observation study relied on observed counts of alcoholic drinks consumed [80], all the other studies relied on self-reported data, including one that compared perceived levels of alcohol consumption by peers to self-reported alcohol consumption by participants [79].

**Statistical analyses**

The statistical analyses used to assess social network characteristics were also heterogeneous, although the majority used some form of regression modeling correcting for nonindependence of observations/autocorrelation among network members. The longitudinal studies used Generalized Estimating Equations (GEE) to account for repeated measures. Overall, the methodologies described by the included studies were rigorous enough that the studies met inclusion criteria based on the quality assessment tool (mean = 95%).

**Findings**

All the included studies reported a statistically significant association between a social network characteristic and an alcohol-related outcome. The different types of social network members whose alcohol consumption (or in one study, their beliefs about alcohol [76]) was associated with participants’ alcohol consumption, included: peers/friends [69, 70, 74, 76, 78, 80, 82, 83], dorm mates [68, 73, 79], drug network members [75], and parents [76]. In one study, participants’ alcohol consumption was associated with alcohol consumption of relatives’ and friends’ but not that of immediate neighbors or co-workers [82].

Social network members’ drinking behaviors were associated with participants’ drinking behaviors in multiple ways. For example, among first-year university students in Germany, participants’ quantity of drinking was associated with friends’ quantity of drinking but participants’ frequency of drinking was only associated with friends who also identified the participant as a friend [71]. At a medium-sized university in the Northeast US, weekly volume of alcohol consumed among nominated peers was significantly associated with that of participants but alcohol problems (measured using the 24-item Brief-Young Adult Alcohol Consequences Questionnaire [84]) were not [68]. In a subsequent study that sampled the entire first-year class at the same university, participant’s binge drinking frequency was positively associated with both perceived and actual binge drinking frequency of important peers, and resistance to peer influence weakened the effect of perceived peer binge drinking on participant binge drinking, but did not interact with actual norms [70]. In a sub-sample of past-month drinkers from the previous study, the number of drinks consumed by your peers on their heaviest drinking occasion was associated with greater drinking quantities on one’s own heaviest drinking occasion [78]. Among black men who have sex with men (MSM) in a community setting in South Africa, individuals whose social networks included a higher proportion of hazardous drinkers were more likely to be hazardous drinkers themselves [74]. In the naturalistic observation study, peer group alcohol consumption was the strongest predictor of participants’ alcohol consumption [80]. Data from the Framingham Heart Study was used to show how the
impact of peers drinking habits on one’s own drinking behaviors diminished across degrees of separation, i.e. one’s own friends influence drinking more than the friends of one’s friends [82].

A few studies looked at peer effects in social networks by examining homophily [68, 81, 82]. One study showed that quantity of alcohol consumption clustered within nominated peers of a university residence hall, then used regression to show that participants’ quantity of alcohol consumption was associated with nominated peers’ quantity of alcohol consumption [68]. Two studies observed that homophily increased over time (i.e. social networks became more homophilous), and provided support for induction because the directionality of friendship nominations mattered after controlling for participants’ previous alcohol consumption [81, 82].

Certain studies assessed associations between other aspects of social network structure than homophily (sometimes in addition to looking at the association between social network members drinking behaviors and participants’ drinking behaviors), such as network size, network shape, network attributes or position within a network, and alcohol-related outcomes [67, 72, 77]. For example, among university students in the US, outdegree was positively associated with number of heavy drinking days [67]. In the same study, betweenness centrality was positively associated with alcohol-related problems, with a stronger association among women [67]. In a subsequent study that sampled the entire first-year class at the same university, popularity (indegree) was positively associated with participants’ alcohol consumption, binge drinking frequency, and alcohol-related problems [69]. In a sub-sample of past-month drinkers from the previous study, being present at other peers’ heaviest drinking occasions was associated with greater drinking quantities on one’s own heaviest drinking occasion [78]. Among university students in Belgium, indegree was positively associated with binge drinking, while gender heterophily and effective size were negatively associated [77]. Among young, MSM in a community setting in the US, transitivity was positively associated with frequency of alcohol and/or drug use [72]. Taken together, these findings suggest that characteristics of social networks and one’s position in a social network also are associated with alcohol-related outcomes.

**Critical evaluation**

Almost all (15 out of 17) of the included studies were conducted in young adults [67–74, 76–81, 83], mostly in university settings [67–71, 73, 76–81], with just 2 in community settings [72, 74]. Two studies were conducted among adults whose mean age was greater than 30 [75, 82]. Considering the ways that social networks are formed, it is possible that school settings, in which individuals live in close proximity to similar-aged peers who share a large number of commonalities, have a qualitatively different effect on the ways that social networks are formed and how information is transmitted through these networks than networks of older adults or those in community settings.

The variation in measures used, both of social network characteristics and alcohol consumption, makes it challenging to summarize the body of evidence for how social networks influence alcohol consumption in young adults, and vice versa. Also as a limitation, many of the studies were cross-sectional [67–70, 72–74, 77–79, 83]. Cross-sectional designs allow researchers to test for correlations between an individuals’ alcohol consumption and that of their peers, but not to distinguish whether the correlations result from selection, confounding or induction (i.e. that the observed homophily with regards to alcohol consumption observed among social networks of adults is due to the tendency for people to befriend those similar to themselves, the effects of shared environments, or the spread of drinking behaviors within networks). Two studies examined directionality and found support for induction [81, 82].
Some studies collected data on complete networks \[77, 81\] or used complete lists of members in a social network (i.e. rosters) but limited the number of peers that participants were able to nominate \[67–71, 73, 78, 79\]. Other studies relied on peer nominations or recruitment without the availability of rosters \[72, 74–76, 80, 82, 83\]. The studies with less complete networks suffer from missing data that raise doubt about whether the results apply to the entire network, and whether the network metrics are accurate. Dyadic index-peer data can provide useful information, but is incomplete social network data because it limits researchers to investigation of the effects of peer consumption rather than social network position or other characteristics of social network structure. Such studies contribute only limited information about how social networks influence adult alcohol use. Furthermore, results that rely on incomplete social network data are likely to suffer from selection bias because peers who are closer to the participant (and thus, more likely to share similar characteristics) are more likely to be selected into the study. While many of the studies in adults were limited in the completeness of social network data collected; collectively, they featured a wide variety of types of social network members studied (e.g. peers/friends, classmates/dormmates, drug network members, relatives/parents, neighbors, co-workers). In a few of the studies \[72, 74, 83\], the nature of the relationships among participants was not even known, just that there was some sort of connection between them because one participant’s recruitment was attributed to the other. This is reflective of how peer groups are more expansive and diverse in adulthood \[60\], but also more difficult to capture completely. In nearly all cases, these social network members were found to influence participant alcohol consumption. Lastly, many of the included studies were conducted among specific populations (e.g. fraternity brothers \[81\], injection drug users \[75\], men who have sex with men \[72, 74\]), raising questions about the generalizability of the findings.

**Discussion**

Through a systematic review, 17 studies were identified and evaluated to assess the evidence on whether social network characteristics were associated with drinking behaviors in adults. These studies measured and analyzed social networks in various ways. The heterogeneity of methods used make it difficult to generalize about how, specifically, social networks influence alcohol consumption and vice versa. However, in young adults, among whom the majority of studies were conducted, with whom they socialize and how they socialize appears to be associated with alcohol consumption across methodologies and settings.

This review identified a lack of research on social network characteristics and alcohol consumption among middle-aged or older adults. Therefore, there is limited evidence to infer how social networks are associated with alcohol consumption further into adulthood, although it is likely quite different for a number of reasons. First, social network dynamics differ throughout the lifespan \[60\]. For example, as adolescents enter into young adulthood, their social networks tend to grow in size, and the strength of peer dynamics remain strong, especially when young adults are located in settings with relatively complete (i.e. bounded) social networks, such as universities \[62\]. The influence of peers is believed to wane in later adulthood \[62\]. Second, drinking patterns also change during the life course \[2, 85\]. For example, entering college \[86\] or meeting the legal minimal age to purchase alcohol are known to alter drinking behaviors and alcohol-related harms \[87\]. Third, alcohol use also has changing physiological effects as individuals age \[88\], with increasing health risks associated with aging \[89–91\]. Whether sociometric social network data would be particularly informative for examining alcohol use in older adults remains an open question, especially given that network effects might be waning \[62\]. Sorting out these questions remains an area that requires further
Another important area that was not explored in the literature that we identified is a comparison of the impact of social networks on alcohol use between adults and adolescents. Using a life course perspective to explore the changing impacts of social networks on alcohol use could be further enlightening.

An important question is whether social network analysis-based peer effects on drinking are different in adults than in adolescents. No reviewed studies directly investigated this. One study [92] investigated the effects of adolescent social network characteristics on participants in the National Longitudinal Study of Adolescent to Adult Health (Add Health) [58] when they were adolescents and then re-examined the effects of the adolescent social network characteristics on participants when they had become young adults. One characteristic, adolescent group integration, showed a weaker effect on binge drinking in adulthood than adolescence, while another adolescent social network characteristic, prestige, showed an increased effect on adult binge drinking, suggesting that the lasting effects of adolescent social network analysis-based peer effects into adulthood varied depending on the characteristic considered. However, this study was not included in the main review because it did not meet inclusion criteria (the social network recruitment was done during adolescence, not adulthood). Comparing how the studies in the current review on adults differed from the studies in the previous review that included studies of adolescents [57]: in adolescents, the social network data collected was much more complete and many social network characteristics were able to be explored, yet peer effects were almost exclusively examined in schoolmates, with studies distinguishing further about friendship, closeness, reciprocity, and shared affiliations (e.g., sports or club activities). The relationships studied in the social network literature among adults were more extensive, and included peers/friends, classmates/dormmates, drug network members, relatives/parents, neighbors, co-workers. While having more expansive and diverse social networks as adults makes collecting complete social network data more costly and challenging, one of the benefits of collecting this information is that they will help us more fully understand how social networks characteristics affect alcohol consumption among adults.

Social network research methods are still relatively novel for studying alcohol use in adults, with 14 of the 17 included papers published since 2010. This literature is likely to continue growing as social network research is expanding [50, 93], and methodologies are being refined [13]. This review demonstrates the adaptability of social network analysis to study alcohol consumption, which is a prime topic for social network research as drinking (unlike many other health-related behaviors) is often undertaken as a shared social activity. The social aspects of drinking are especially evident in teens and young adults, but not as clear as people get older. Hopefully, as this field grows, more studies will be conducted among older adults and in community settings, where sociometric network data is more challenging to collect, but potentially more informative.

This review and the study results have several limitations. First, only 17 studies were identified and deemed eligible to be included based on relevance and quality. Articles may have been missed because the use of social network methods was not indicated in the title or abstract and thus they would not have been identified during the literature search. However, for that reason, a broad search was conducted and ultimately a large number (5,510) of articles were screened based on title and abstract. Second, all studies included in the review reported at least one statistically significant association; this might be a reflection of publication bias. Third, the results of social network analysis studies are context-specific, and insights are likely to vary based on setting and the exposures and the outcomes that were measured. Furthermore, even findings within studies varied by whether the outcome was frequency of alcohol consumption, quantity of alcohol consumption, or binge drinking. It might be important to consider
implementing some level of standardization across social network studies, and to prioritize assessing the replicability of findings in different settings.

Despite the limitations, this review identified numerous studies that have applied social network analysis to study alcohol consumption in (mostly young) adult populations. Social network analysis is a method that helps us better understand alcohol use in young adults because it not only addresses the actual drinking behaviors of their peers, but also uniquely addresses how various characteristics of social network structure (e.g. homophily, popularity, transitivity) are associated with individual alcohol use. In other words, how young adults socialize and who they socialize with appears to matter when alcohol consumption is considered. In this sense, social network analysis is a useful tool with the potential to explore the effects of social mixing patterns on alcohol consumption.

Implications for research and intervention

There are a few important take-away messages from this first review of the growing number of empirical studies that have used social network analysis to explore alcohol use in adults. First, peer alcohol use and other social network characteristics (e.g. network attributes or position within a network) were associated with adults' alcohol consumption across studies. Second, we identified a lack of research on the impact of social networks on alcohol use in middle-age and older adults, especially those residing in community settings (i.e. without explicit boundaries). Future empirical research should work to address these gaps in our understanding. Efforts should also be made to reduce heterogeneity in social network analysis studies (e.g. agreeing on standardized definitions of social network measures, assessing and reporting the results of them consistently) to facilitate generalizability. This review informs alcohol researchers, health service providers, and policymakers about how social networks have been studied, thus far, to better understand alcohol consumption. As social networks appear to play a role in the consumption of alcohol in young adulthood, this suggests potential for interventions that utilize social networks to help reduce the burden of harmful alcohol consumption [92]. Interventions that utilize social networks to promote behavior change are increasingly available [44], calling for studies of their feasibility and efficacy in reducing alcohol consumption in young adult populations.

Supporting information

S1 Table. PRISMA 2009 checklist.
(DOCX)

S2 Table. Literature review database search strategy and terms.
(DOCX)

S3 Table. Quality assessment tool.
(DOCX)

S4 Table. Quality assessment of articles selected for review.
(DOCX)

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References

1. Collaborators GBDA. Alcohol use and burden for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2018; 392(10152):1015–35. Epub 2018/08/28. https://doi.org/10.1016/S0140-6736(18)31310-2 PMID: 30146330; PubMed Central PMCID: PMC6148333.

2. Grant BF, Chou SP, Saha TD, Pickering RP, Kerridge BT, Ruan WJ, et al. Prevalence of 12-Month Alcohol Use, High-Risk Drinking, and DSM-IV Alcohol Use Disorder in the United States, 2001–2002 to 2012–2013: Results From the National Epidemiologic Survey on Alcohol and Related Conditions. JAMA Psychiatry. 2017; 74(9):911–23. Epub 2017/06/10. https://doi.org/10.1001/jamapsychiatry.2017.2161 PMID: 28793133; PubMed Central PMCID: PMC5710229.

3. Grant BF, Goldstein RB, Saha TD, Chou SP, Jung J, Zhang H, et al. Epidemiology of DSM-5 Alcohol Use Disorder: Results From the National Epidemiologic Survey on Alcohol and Related Conditions III. JAMA Psychiatry. 2015; 72(8):757–66. Epub 2015/06/04. https://doi.org/10.1001/jamapsychiatry.2015.0584 PMID: 26039070; PubMed Central PMCID: PMC5240584.

4. Hasin DS, Wall M, Witkiewitz K, Kranzler HR, Falk D, Litten R, et al. Change in non-abstinent WHO drinking risk levels and alcohol dependence: a 3 year follow-up study in the US general population. Lancet Psychiatry. 2017; 4(6):469–76. Epub 2017/05/01. https://doi.org/10.1016/S2215-0366(17)30130-X PMID: 28456501; PubMed Central PMCID: PMC5538661.

5. CDC. Fact Sheets—Alcohol Use and Your Health [updated July 25, 2016January 8, 2018]. Available from: https://www.cdc.gov/alcohol/fact-sheets/alcohol-use.htm.

6. Room R, Babor T, Rehm J. Alcohol and public health. Lancet. 2005; 365(9458):519–30. Epub 2005/02/12. https://doi.org/10.1016/S0140-6736(05)17870-2 PMID: 15705462.

7. Rehm J, Gmel G, Sempos CT, Trevisan M. Alcohol-related morbidity and mortality. Alcohol Res Health. 2003; 27(1):39–51. Epub 2004/08/11. PMID: 15301399.

8. Rehm J. Alcohol and all-cause mortality. Int J Epidemiol. 1996; 25(1):215–6; author reply 8–20. Epub 1996/02/01. https://doi.org/10.1093/ije/25.1.215 PMID: 8664939.

9. Lewis-Laitemark C, Wettlaufer A, Shiel KD, Giesbrecht N, April N, Asbridge M, et al. The effects of alcohol-related harms to others on self-perceived mental well-being in a Canadian sample. Int J Public Health. 2017; 62(6):669–78. Epub 2016/12/03. https://doi.org/10.1007/s00038-016-0924-7 PMID: 27900393.

10. Greenfield TK, Karriker-Jaffe KJ, Kaplan LM, Kerr WC, Wilsnack SC. Trends in Alcohol’s Harms to Others (AHTO) and Co-occurrence of Family-Related AHTO: The Four US National Alcohol Surveys, 2000–2015. Subst Abuse. 2015; 9(Suppl 2):23–31. Epub 2015/11/10. https://doi.org/10.4137/SART.S23505 PMID: 26549971; PubMed Central PMCID: PMC4624092.

11. Hasin DS, Stinson FS, Ogburn E, Grant BF. Prevalence, correlates, disability, and comorbidity of DSM-IV alcohol abuse and dependence in the United States: results from the National Epidemiologic Survey on Alcohol and Related Conditions. Arch Gen Psychiatry. 2007; 64(7):830–42. Epub 2007/07/04. https://doi.org/10.1001/archpsyc.64.7.830 PMID: 17606817.

12. Bronfenbrenner U. The ecology of human development: experiments by nature and design. Cambridge, Mass.: Harvard University Press; 1979. xv, 330 p.

13. Valente TW, Gallaher P, Mouttapa M. Using social networks to understand and prevent substance use: a transdisciplinary perspective. Substance use & misuse. 2004; 39(10–12):1685–712. Epub 2004/12/14. PMID: 15587948.
14. Livak B, Schneider JA. Using sociometric measures to assess nonresponse bias. Ann Epidemiol. 2014; 24(7):554–7. Epub 2014/06/18. https://doi.org/10.1016/j.annepidem.2014.04.006 PMID: 24935468; PubMed Central PMCID: PMC4128320.

15. Wolfson S. Students’ estimates of the prevalence of drug use: evidence for a false consensus effect. Psychol Addict Behav. 2000; 14(3):295–8. Epub 2000/09/22. PMID: 10998955.

16. Fujimoto K, Valente TW. Decomposing the components of friendship and friends’ influence on adolescent drinking and smoking. J Adolesc Health. 2012; 51(2):136–43. Epub 2012/07/25. https://doi.org/10.1016/j.jadohealth.2011.11.013 PMID: 22824443; PubMed Central PMCID: PMC3404406.

17. Fujimoto K, Valente TW. Social network influences on adolescent substance use: disentangling structural equivalence from cohesion. Soc Sci Med. 2012; 74(12):1952–60. Epub 2012/04/06. https://doi.org/10.1016/j.socscimed.2012.02.009 PMID: 22475405; PubMed Central PMCID: PMC3354645.

18. Fujimoto K, Valente TW. Alcohol peer influence of participating in organized school activities: a network approach. Health Psychol. 2013; 32(10):1084–92. Epub 2012/08/29. https://doi.org/10.1037/a0029466 PMID: 22924449; PubMed Central PMCID: PMC3971990.

19. Choi KH, Ning Z, Gregorich SE, Pan QC. The influence of social and sexual networks in the spread of HIV and syphilis among men who have sex with men in Shanghai, China. J Acquir Immune Defic Syndr. 2007; 45(1):77–84. Epub 2007/02/28. https://doi.org/10.1097/QAI.0b013e3180415dd7 PMID: 17325608.

20. Laumann EO, Youm Y. Racial/ethnic group differences in the prevalence of sexually transmitted diseases in the United States: a network explanation. Sex Transm Dis. 1999; 26(5):250–61. Epub 1999/05/20. PMID: 10333277.

21. Youm Y, Laumann EO. Social network effects on the transmission of sexually transmitted diseases. Sex Transm Dis. 2002; 29(11):689–97. Epub 2002/11/20. PMID: 12438906.

22. Kelly JA, Amirkhanian YA, Seal DW, Galletly CM, DiFranceisco W, Glasman LR, et al. Levels and predictors of sexual HIV risk in social networks of men who have sex with men in the Midwest. Aids Educ Prev. 2010; 22(6):483–95. PMID: 21204625.

23. Doherty IA, Padian NS, Marlow C, Aral SO. Determinants and consequences of sexual networks as they affect the spread of sexually transmitted Infections. Journal of Infectious Diseases. 2005; 191: 85–93. Epub 2005/07/01. PMID: 15904295.

24. Broadhead RS, Heckathorn DD, Weakliem DL, Anthony DL, Madray H, Mills RJ, et al. Harnessing peer networks as an instrument for AIDS prevention: results from a peer-driven intervention. Public health reports. 1998; 113 Suppl 1:42–57. Epub 1998/12/16. PMID: 9722809; PubMed Central PMCID: PMC1307726.

25. Latkin CA. Outreach in natural settings: the use of peer leaders for HIV prevention among injecting drug users’ networks. Public health reports. 1998; 113 Suppl 1:151–9. Epub 1998/12/16. PMID: 9722820; PubMed Central PMCID: PMC1307737.

26. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. N Engl J Med. 2007; 357(4):370–9. Epub 2007/07/27. https://doi.org/10.1056/NEJMsa066082 PMID: 17562552.

27. Cohen-Cole E, Fletcher JM. Is obesity contagious? Social networks vs. environmental factors in the obesity epidemic. J Health Econ. 2008; 27(5):1382–7. Epub 2008/06/24. https://doi.org/10.1016/j.jhealeco.2008.04.009 PMID: 18571258.

28. Ali MM, Dwyer DS. Social network effects in alcohol consumption among adolescents. Addict Behav. 2010; 35(4):337–42. Epub 2010/01/07. https://doi.org/10.1016/j.addbeh.2009.12.002 PMID: 20051311.

29. Balsa AI, Homer JF, French MT, Norton EC. Alcohol Use and Popularity: Social Payoffs from Conforming to Peers’ Behavior. J Res Adolesc. 2011; 21(3):559–68. Epub 2011/08/24. https://doi.org/10.1111/j.1532-7795.2010.00704.x PMID: 21605822; PubMed Central PMCID: PMC3158622.

30. Cheadle JE, Stevens M, Williams DT, Goosby BJ. The differential contributions of teen drinking homophily to new and existing friendships: An empirical assessment of assortative and proximity selection mechanisms. Soc Sci Res. 2013; 42(5):1297–310. Epub 2013/07/19. https://doi.org/10.1016/j.ssrresearch.2013.05.001 PMID: 23859732; PubMed Central PMCID: PMC3717352.

31. Cruz JE, Emery RE, Turkheimer E. Peer network drinking predicts increased alcohol use from adolescence to early adulthood after controlling for genetic and shared environmental selection. Dev Psychol. 2012; 48(5):390–402. Epub 2012/03/07. https://doi.org/10.1037/a0027515 PMID: 22390657; PubMed Central PMCID: PMC3616841.

32. Deutsch AR, Chernyavsky P, Steinley D, Slutske WS. Measuring peer socialization for adolescent substance use: a comparison of perceived and actual friends’ substance use effects. J Stud Alcohol Drugs. 2015; 76(2):267–77. Epub 2015/03/19. https://doi.org/10.15288/jsad.2015.76.267 PMID: 25785802; PubMed Central PMCID: PMC374479.
33. Deutsch AR, Steinley D, Slutske WS. The role of gender and friends’ gender on peer socialization of adolescent drinking: a prospective multilevel social network analysis. J Youth Adolesc. 2014; 43 (9):1421–35. Epub 2013/10/31. https://doi.org/10.1007/s10964-013-0048-9 PMID: 24170437; PubMed Central PMCID: PMC4497576.

34. Hatzenbuehler ML, McLaughlin KA, Xuan Z. Social networks and sexual orientation disparities in tobacco and alcohol use. J Stud Alcohol Drugs. 2015; 76(1):117–26. Epub 2014/12/09. PMID: 25486400; PubMed Central PMCID: PMC4263773.

35. Mundt MP. The impact of peer social networks on adolescent alcohol use initiation. Acad Pediatr. 2011; 11(5):414–21. Epub 2011/07/29. https://doi.org/10.1016/j.acap.2011.05.005 PMID: 21795133; PubMed Central PMCID: PMC3170443.

36. Kottiri BJ, Friedman SR, Neaigus A, Curtis R, Des Jarlais DC. Risk networks and racial/ethnic differences in the prevalence of HIV infection among injection drug users. Journal of Acquired Immune Deficiency Syndromes. 2002; 30(1):95–104. ISI:000175401600013. PMID: 12048369.

37. Friedman SR, Aral S. Social networks, risk-potential networks, health, and disease. J Urban Health. 2001; 78(3):411–8. Epub 2001/09/21. https://doi.org/10.1093/jurban/78.3.411 PMID: 11564845; PubMed Central PMCID: PMC3455917.

38. Friedman SR, Neaigus A, Jose B, Curtis R, Goldstein M, Idefonso G, et al. Sociometric risk networks and risk for HIV infection. Am J Public Health. 1997; 87(8):1289–96. Epub 1997/08/01. https://doi.org/10.2105/ajph.87.8.1289 PMID: 9279263; PubMed Central PMCID: PMC1381088.

39. Smith KP, Christakis NA. Social Networks and Health. Annual Review of Sociology. 2008; 34(1):405–29. https://doi.org/10.1146/annurev.soc.34.040507.134601 PMID: 1833458; PubMed Central PMCID: PMC4117829.

40. Israel BA. Social networks and health status: linking theory, research, and practice. Patient Couns Health Educ. 1982; 4(2):65–79. Epub 1981/12/12. PMID: 10258419.

41. Umberson D, Montez JK. Social relationships and health: a flashpoint for health policy. J Health Soc Behav. 2010; 51 Suppl:S54–66. Epub 2010/12/22. https://doi.org/10.1177/0022146510383501 PMID: 20943583; PubMed Central PMCID: PMC3150158.

42. Johnson BT, Redding CA, DiClemente RJ, Mustanski BS, Dodge B, Sheeran P, et al. A network-individual-resource model for HIV prevention. Aids Behav. 2010; 14(5 Suppl);204–21. Epub 2010/09/24. https://doi.org/10.1007/s10461-010-9803-z PMID: 20862606; PubMed Central PMCID: PMC4361779.

43. Berkman LF, Glass T, Social integration, social networks, social support, and health. In: Berkman LF, Kawachi I, editors. Social epidemiology. New York: Oxford University Press; 2000. p. 137–73.

44. Valente TW. Network interventions. Science. 2012; 337(6090):49–53. Epub 2012/07/07. https://doi.org/10.1126/science.1217330 PMID: 22767921.

45. Latkin C, Donnell D, Celentano DD, Aramrattna A, Liu TY, Vongchak T, et al. Relationships between social norms, social network characteristics, and HIV risk behaviors in Thailand and the United States. Health Psychol. 2009; 28(3):323–9. Epub 2009/05/20. https://doi.org/10.1177/0278613308330104 PMID: 19450038; PubMed Central PMCID: PMC2799116.

46. Luke DA, Harris JK. Network analysis in public health: history, methods, and applications. Annu Rev Publ Health. 2007; 28:69–93. Epub 2007/01/16. https://doi.org/10.1146/annurev.publhealth.28.021406.144132 PMID: 17222078.

47. Friedman SR, Bolyard M, Mateu-Gelabert P, Goltzman P, Pawlowicz MP, Singh DZ, et al. Some data-driven reflections on priorities in AIDS network research. AIDS Behav. 2007; 11(5):641–51. Epub 2006/10/21. https://doi.org/10.1007/s10461-006-9166-7 PMID: 17053857.

48. Valente TW, Fosados R. Diffusion of innovations and network segmentation: the part played by people in promoting health. Sex Transm Dis. 2006; 33(7 Suppl):S23–31. Epub 2006/06/24. https://doi.org/10.1097/01.olq.0000221018.32533.6d PMID: 16794552.

49. Schneider JA, Zhou AN, Laumann EO. A new HIV prevention network approach: sociometric peer change agent selection. Soc Sci Med. 2015; 125:192–202. Epub 2014/02/13. https://doi.org/10.1016/j.sscmed.2013.12.034 PMID: 24518188; PubMed Central PMCID: PMC4117829.

50. Borgatti SP, Mehra A, Brass DJ, Labianca G. Network analysis in the social sciences. Science. 2009; 323(5916):892–5. Epub 2009/02/14. https://doi.org/10.1126/science.1165821 PMID: 19213908.

51. Valente TW. Social networks and health: models, methods, and applications. Oxford; New York: Oxford University Press; 2010. xiv, 277 p. p.

52. Alexander C, Piazza M, Mekos D, Valente T. Peers, schools, and adolescent cigarette smoking. J Adolesc Health. 2001; 29(1):22–30. Epub 2001/06/29. PMID: 11429302.

53. Smith AM, Grierson J, Wain D, Pitts M, Pattison P. Associations between the sexual behaviour of men who have sex with men and the structure and composition of their social networks. Sex Transm Infect. 2004; 80(6):455–8. Epub 2004/12/02. https://doi.org/10.1136/sti.2004.010355 PMID: 15572613; PubMed Central PMCID: PMC1744944.
54. Helleringer S, Kohler HP. Sexual network structure and the spread of HIV in Africa: evidence from Likoma Island, Malawi. Aids. 2007; 21(17):2323–32. Epub 2007/12/20. https://doi.org/10.1097/QAD.0b013e328285df98 PMID: 18090281.

55. Parental Windle M., sibling, and peer influences on adolescent substance use and alcohol problems. Applied Developmental Science. 2000; 4:98–110.

56. Predisposition Gaughan M. and pressure : mutual influence and adolescent drunkenness. Connections. 2003; 25(2):17–31.

57. K.C., J. P. G. US adolescents’ friendship networks and health risk behaviors: a systematic review of studies using social network analysis and Add Health data. PeerJ. 2015; 3:e1052. https://doi.org/10.7717/peerj.1052 PMID: 26157622

58. Resnick MD, Bearman PS, Blum RW, Bauman KE, Harris KM, Jones J, et al. Protecting adolescents from harm. Findings from the National Longitudinal Study on Adolescent Health. JAMA. 1997; 278(10):823–32. Epub 1997/09/18. https://doi.org/10.1001/jama.278.10.823 PMID: 9293990.

59. Burk WJ, van der Vorst H, Kerr M, Stattin H. Alcohol use and friendship dynamics: selection and socialization in early-, middle-, and late-adolescent peer networks. J Stud Alcohol Drugs. 2012; 73(1):89–98. Epub 2011/12/14. https://doi.org/10.15288/jsad.2012.73.89 PMID: 22152666.

60. W.W., H. N. S. Friendships and adaptation in the life course. Psychological bulletin. 1997; 121(3):355–70.

61. Valente TW. Social network influences on adolescent substance use: An introduction. Connections. 2003; 25(2):11–6.

62. Wrzus C, Hanel M, Wagner J, Neyer FJ. Social network changes and life events across the life span: a meta-analysis. Psychol Bull. 2013; 139(1):53–80. Epub 2012/05/31. https://doi.org/10.1037/a0028601 PMID: 22642230.

63. Liberati A, Altman DG, Tetzlaff J, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLoS Med. 2009; 6(7):e1000100. Epub 2009/07/22. https://doi.org/10.1371/journal.pmed.1000100 PMID: 19621070; PubMed Central PMCID: PMC2707010.

64. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(7):e1000097. Epub 2009/07/22. https://doi.org/10.1371/journal.pmed.1000097 PMID: 19621072; PubMed Central PMCID: PMC2707599.

65. Barnett NP, Ott MQ, Clark MA. The relevance of network prominence and reciprocity of relationships for alcohol use and alcohol-related problems in a college residence hall network. Psychol Addict Behav. 2014; 28(4):980–9. Epub 2014/12/22. https://doi.org/10.1037/a0038354 PMID: 25528047.

66. Janulis P, Birkett M, Phillips G 2nd, Mustanski B. Substance use network characteristics and drug and alcohol use behaviors among young men who have sex with men (YMSM). Drug and alcohol dependence. 2015; 157:188–91. Epub 2015/10/21. https://doi.org/10.1016/j.drugalcdep.2015.10.003 PMID: 26483355; PubMed Central PMCID: PMC4663132.
73. Kenney SR, Ott M, Meisel MK, Barnett NP. Alcohol perceptions and behavior in a residential peer social network. Addict Behav. 2017; 64:143–7. Epub 2016/10/19. https://doi.org/10.1016/j.addbeh.2016.08.047 PMID: 27614052; PubMed Central PMCID: PMC5428385.

74. Knox J, Reddy V, Lane T, Lovasi G, Hasin D, Sandfort T. Determinants of hazardous drinking among black South African men who have sex with men. Drug and alcohol dependence. 2017; 180:14–21. Epub 2017/08/30. https://doi.org/10.1016/j.drugalcdep.2017.07.036 PMID: 28850902; PubMed Central PMCID: PMC5648600.

75. Latkin CA, Mandell W, Vlahov D. The relationship between risk networks’ patterns of crack cocaine and alcohol consumption and HIV-related sexual behaviors among adult injection drug users: a prospective study. Drug and alcohol dependence. 1996; 42(3):175–81. Epub 1996/11/01. PMID: 8912800.

76. Lau RR, Quadrel MJ, Hartman KA. Development and change of young adults’ preventive health beliefs and behavior: influence from parents and peers. J Health Soc Behav. 1990; 31(3):240–59. Epub 1990/09/01. PMID: 2133479.

77. Lorant V, Nicaise P. Binge drinking at University: a social network study in Belgium. Health promotion international. 2015; 30(3):675–83. Epub 2014/03/14. https://doi.org/10.1093/heapro/dau007 PMID: 24622535.

78. Meisel MK, DiBello AM, Balestrieri SG, Ott MQ, DiGuiseppe GT, Clark MA, et al. An event- and network-level analysis of college students’ maximum drinking day. Addict Behav. 2018; 79:189–94. Epub 2018/01/02. https://doi.org/10.1016/j.addbeh.2017.12.030 PMID: 29291510; PubMed Central PMCID: PMC5807110.

79. Ott MQ, Hogan JW, Gile KJ, Linkletter C, Barnett NP. Bayesian Peer Calibration with Application to Alcohol Use. Statistics in medicine. 2016; 35(19):3303–18. Epub 2016/03/05. https://doi.org/10.1002/sim.6925 PMID: 26940774; PubMed Central PMCID: PMC5457837.

80. Overbeek G, Bot SM, Meeus WHJ, Sentse M, Knibbe RA, Engels R. Where it’s at! The role of best friends and peer group members in young adults’ alcohol use. Journal of Research on Adolescence. 2011; 213(3):631–8. https://doi.org/10.1111/j.1532-7715.2011.00444.x 2011-161 79-003.

81. Phua J. The influence of peer norms and popularity on smoking and drinking behavior among college fraternity members: A social network analysis. Social Influence. 2011; 6(3):153–68. https://doi.org/10.1080/15534 510.2011.584445 2011-161 79-003.

82. Rosenquist JN, Murabito J, Fowler JH, Christakis NA. The spread of alcohol consumption behavior in a large social network. Annals of internal medicine. 2010; 152(7):426–33, W141. Epub 2010/04/07. https://doi.org/10.7326/0003-4819-152-7-201004060-00007 PMID: 20368648; PubMed Central PMCID: PMC3343772.

83. Tucker JA, Cheong J, Chandler SD, Crawford SM, Simpson CA. Social networks and substance use among at-risk emerging adults living in disadvantaged urban areas in the southern United States: a cross-sectional naturalistic study. Addiction. 2015; 110(9):1524–32. Epub 2015/06/09. https://doi.org/10.1111/add.13010 PMID: 26054041.

84. Cahalane CW, Strong DR, Read JP. Toward efficient and comprehensive measurement of the alcohol problems continuum in college students: the brief young adult alcohol consequences questionnaire. Alcohol Clin Exp Res. 2005; 29(7):1180–9. Epub 2005/07/28. PMID: 16046873.

85. Britton A, Ben-Shlomo Y, Benzeval M, Kuh D, Bell S. Life course trajectories of alcohol consumption in the United Kingdom using longitudinal data from nine cohort studies. BMC Med. 2015; 13:47. Epub 2015/04/11. https://doi.org/10.1186/s12916-015-0273-z PMID: 25858476; PubMed Central PMCID: PMC4351673.

86. Borsari B, Carey KB. Peer influences on college drinking: a review of the research. J Subst Abuse. 2001; 13(4):391–424. Epub 2002/01/05. PMID: 11775073.

87. DeJong W, Blanchette J. Case closed: research evidence on the positive public health impact of the age 21 minimum legal drinking age in the United States. J Stud Alcohol Drugs Suppl. 2014; 75 Suppl 17:108–15. Epub 2014/02/26. PMID: 24564041.

88. Meier P, Seitz HK. Age, alcohol metabolism and liver disease. Curr Opin Clin Nutr Metab Care. 2008; 11(1):21–6. Epub 2007/12/20. https://doi.org/10.1097/MCO.0b013e328230564 PMID: 18080653.

89. Holton A, Boland F, Gallagher P, Fahey T, Kenny R, Cousins G. Life Course Transitions and Changes in Alcohol Consumption Among Older Irish Adults: Results From The Irish Longitudinal Study on Ageing (TILDA). J Aging Health. 2018; 29(7):1180–9. Epub 2018/07/17. https://doi.org/10.1177/ 089824318783080 PMID: 29947553.

90. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012; 380 (9859):2224–60. Epub 2012/12/19. https://doi.org/10.1016/S0140-6736(12)61766-8 PMID: 23245609; PubMed Central PMCID: PMC4156511.
91. Rehm J, Gmel GE Sr., Gmel G, Hasan OSM, Imtiaz S, Popova S, et al. The relationship between different dimensions of alcohol use and the burden of disease—an update. Addiction. 2017; 112(6):968–1001. Epub 2017/02/22. https://doi.org/10.1111/add.13757 PMID: 28220587; PubMed Central PMCID: PMC5434904.

92. Hahm HC, Kolaczyk E, Jang J, Swenson T, Bhindarwala AM. Binge drinking trajectories from adolescence to young adulthood: the effects of peer social network. Subst Use Misuse. 2012; 47(6):745–56. Epub 2012/03/29. https://doi.org/10.3109/10826084.2012.666313 PMID: 22452735; PubMed Central PMCID: PMC3391312.

93. Shelton RC, Lee M, Brotzman LE, Crookes DM, Jandorf L, Erwin D, et al. Use of social network analysis in the development, dissemination, implementation, and sustainability of health behavior interventions for adults: A systematic review. Soc Sci Med. 2019; 220:81–101. Epub 2018/11/10. https://doi.org/10.1016/j.soscimed.2018.10.013 PMID: 30412922.