Use of social network analysis in the development, dissemination, implementation, and sustainability of health behavior interventions for adults: A systematic review

Rachel C. Shelton[a], **Matthew Lee**[a], **Laura E. Brotzman**[a], **Danielle M. Crookes**[a], **Lina Jandorf**[b], **Deborah Erwin**[c], **Elizabeth Gage-Bouchard**[c]

[a]Columbia University Mailman School of Public Health, Department of Sociomedical Sciences 722 West 168th Street, New York, NY 10032

[b]Icahn School of Medicine at Mount Sinai, Department of Oncological Sciences, One Gustave L. Levy Place, New York, NY 10029

[c]Roswell Park Cancer Institute, Elm and Carlton Streets, Buffalo, NY 14263

Abstract

Interest in conceptualizing, measuring, and applying social network analysis (SNA) in public health has grown tremendously in recent years. While these studies have broadened our understanding of the role that social networks play in health, there has been less research that has investigated the application of SNA to inform health-related interventions. This systematic review aimed to capture the current applied use of SNA in the development, dissemination, implementation, and sustainability of health behavior interventions for adults. We identified 52 articles published between 2004 and 2016. A wide variety of study settings were identified, most commonly in the US context and most commonly related to sexual health and HIV prevention. We found that 38% of articles explicitly applied SNA to inform some aspect of interventions. Use of SNA to inform intervention design (as opposed to dissemination, implementation, or sustainability) was most common. The majority of articles represented in this review (n=39) were quantitative studies, and 13 articles included a qualitative component. Partial networks were most represented across articles, and over 100 different networks measures were assessed. The most commonly described measures were network density, size, and degree centrality. Finally, very few articles defined SNA and not all articles using SNA were theoretically-informed. Given the nascent and heterogeneous state of the literature in this area, this is an important time for the field to coalesce on terminology, measures, and theoretical frameworks in this area. We highlight areas for researchers to advance work on the application of SNAs in the design, dissemination, implementation and sustainability of behavioral interventions.

Keywords

social network analysis; implementation; intervention; health behavior

Introduction

Social networks, through their structural and functional characteristics, have important implications for physical health and health behaviors (Berkman & Glass, 2000; Berkman, Glass, Brissette, & Seeman, 2000; House, Kahn, Cohen, & Syme). The *structure* of social networks (e.g., size, density, interconnectedness among members) has been hypothesized to shape an individual's health behaviors and attitudes by influencing access to resources, opportunities, and constraints (Berkman et al., 2000). *Functional* aspects of social networks, including social support (Cohen, Gottlieb, & Underwood, 2000), social norms (Berkman et al., 2000; Bohnert, Bradshaw, & Latkin, 2009; Latkin et al., 2009; Seo & Huang, 2012), social cohesion (Cohen & Wills, 1985), and social capital (Kawachi & Berkman, 2000), also shape health behaviors and physical health outcomes. Numerous studies have shown the important role that social networks, particularly social support and social integration, have in morbidity and mortality for multiple chronic diseases, including stroke, coronary artery disease, cancer, and obesity (Berkman, Leo-Summers, & Horwitz, 1992; Berkman & Syme, 1979; Greaney et al., 2009; Hammarström, Wiklund, Lindahl, Larsson, & Ahlgren, 2014; Lewis et al., 2001; Michael, Berkman, Colditz, Holmes, & Kawachi, 2002; Uchino, Smith, Holt-Lunstad, Campo, & Reblin, 2007; Vogt, Mullooly, Ernst, Pope, & Hollis, 1992), as well as the negative health consequences of social isolation (Steptoe, Shankar, Demakakos, & Wardle, 2013).

Historically, much research has focused on functional resources that flow through social networks, such as access to social support. While this illuminates one important component of networks, a person's acquisition of resources, information, and support depends on their position in networks. Examination of network structures and characteristics of the 'web of relationships' enhances understanding of how information, resources, and support spread through networks and how possession of these resources is distributed within networks (Rogers, 1995; Valente, 2010; Valente & Rogers, 1995). This is consistent with social network theory (Valente & Pitts, 2017; Erikson & Occhiuto, 2017; Pescosolido & Levy, 2002) that posits the importance of connections or relations for understanding health or other outcomes of individuals, and is evoked when researchers model outcomes as a function of network processes.

There has been a growing literature applying social network analysis (SNA) to public health and behavioral health research over the past 15 years (Christakis & Fowler 2007; Luke & Harris, 2007; Luke, Wald, Carothers, Bach, & Harris, 2013; Valente, Fujimoto, Chou, & Spruijt-Metz, 2009; Valente, Palinkas, Czaja, Chu, & Brown, 2015), which has added a new dimension in understanding the role of social networks in influencing health behaviors and outcomes. SNA is a set of theories, techniques, and tools (Valente, Palinkas, et al., 2015), typically informed by the following guiding principles: 1) networks have structure and network properties that influence system performance; 2) a person's position in a network

influences their behaviors; and 3) people or actors (e.g., organizations) act based on their network environment (Valente, 2015). A growing number of studies among both adolescents and adults have shown that social network structure (e.g., size and density) and peer norms within the structure can influence smoking initiation and smoking (Seo & Huang, 2012), alcohol consumption (Bullers, Cooper, & Russell, 2001), alcohol abstinence (Rosenquist, Murabito, Fowler, & Christakis, 2010), and HIV/STD risk behaviors (Bailey et al., 2007; Davey-Rothwell & Latkin, 2008; Davey–Rothwell & Latkin, 2007; Shaw, Shah, Jolly, & Wylie, 2007). There has been a growing focus on the role of social networks and use of SNA to understand and address obesity (Nam, Redeker, & Whittemore, 2015; Powell et al., 2015). Research suggests that social network characteristics like peer selection and homophily may influence the spread of obesity among both adolescents and adults (Christakis & Fowler 2007; de la Haye, Robins, Mohr, & Wilson, 2010, 2011).

To date, most studies using SNA have sought to understand naturally occurring network processes, and there has been less attention focused on how social network characteristics and use of SNA can be used to inform the development and implementation of health-related interventions. In a review examining use of SNA to inform and design interventions to support the implementation of change in healthcare organizations, Chambers and colleagues (2012) found that almost all of the 52 studies identified were limited to cross-sectional descriptions and observations of networks, and only one involved using the results of SNA as part of an intervention to change practice.

Some studies have suggested the potential for interventions that incorporate SNA to change health behaviors, especially among peer and friendship networks (Jeon & Goodson, 2015). There is some evidence showing greater improvement of risk behaviors among adult network members when the intervention is built off of an existing social network (e.g., peer educators intervene with their network members) or takes a structural network intervention approach (vs. individual-based intervention) (Booth et al., 2011; Latkin et al., 2009). The popular opinion leader (POL) approach builds off the influence of individuals within a network and has been harnessed for health promotion with some success, particularly in the area of HIV/AIDS prevention (Kelly, 2004; Valente, 2006), though there been some challenges in replicating this approach internationally (Elford, Bolding, Davis, Sherr, & Hart, 2004; Group, 2010). Even across POL interventions, there is variation in how POLs are identified (e.g. pre-existing social networks or defined by researchers) and implemented, and not all POL interventions are based on SNA.

Many of the studies to date that have used SNA to inform interventions for adolescent populations. For example, several studies have demonstrated that structuring a school-based tobacco prevention program using network information increased its effectiveness (Valente, Hoffman, Ritt-Olson, Lichtman, & Johnson, 2003; Valente, Unger, Ritt-Olson, Cen, & Anderson Johnson, 2006); specifically, close friendships (e.g., best, popular and mutual friends) were more likely to influence adolescents' smoking behavior than peers outside their network (Alexander, Piazza, Mekos, & Valente, 2001; Pollard, Tucker, Green, Kennedy, & Go, 2010). While promising, there is a limited body of literature on the application of SNA for health behavior intervention development and implementation among adults.

Valente has identified multiple potential applications of SNA during different stages of the intervention and implementation process, including: 1) exploration or needs assessment; 2) adoption or program design; 3) program implementation; and 4) sustainability and monitoring (Valente, Palinkas, et al., 2015). Building off this framework, the purpose of this systematic review is to describe the use and application of SNA to inform interventions, specifically by identifying and reviewing studies that have used SNA to develop, disseminate, implement, and/or sustain social and behavioral health interventions for adults. We focused on adults given that the application of SNA seemed to be an underutilized methodology for interventions for this population. We were specifically interested in documenting how SNA has been used to inform interventions, for what health behaviors, settings, and populations this approach has been used, and which types of methodologies and theories have been applied.

Methods

We conducted a search of articles which utilized SNA to inform the development, dissemination, implementation, and sustainability of health behavior interventions for adults. The search was initially conducted in September 23, 2014 and was updated in March 22, 2016 and December 21, 2016, using the following electronic databases: Ovid Medline, Ovid Medline In-Process & Other Non-Indexed Citations, AMED, Health and Psychosocial Instruments, PsycINFO, EMBASE, CINAHL, SCOPUS, Social Sciences Full Text, and SocIndex. Searches were limited to English-language articles published over 12 years (January 2004 – December 2016). This time period was selected as it was both feasible and comprehensive, with the goal of including relevant articles at a time in which SNA research was growing rapidly. A Boolean search strategy was used to identify the following keywords in the text: (1) (intervention OR program OR trial OR experiment OR evaluation OR dissemination) AND (2) (social relationships OR social network OR social network analysis OR network analysis OR peer network OR peer relation OR egocentric OR sociocentric OR whole network) AND (3) (behav$ OR promot$ OR preven$). Duplicates were identified and removed at each iteration of the search and again during full-text review. The search was supplemented by manual review of the bibliographies of the articles eligible for inclusion in this review.

A total of 15,726 articles were identified in the search process (see Figure 1) (15,599 through online databases and 127 references). This review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, Altman, & The, 2009). Titles and abstracts were independently reviewed by pairs of reviewers (DMC, LI, RCS, EGB, DE, LB) and review of full-text articles was conducted by RCS, EGB, ML, and LB to confirm all inclusion and exclusion criteria were met. All disagreements were discussed and resolved by EGB and RCS. Four inclusion criteria were used to identify the final sample of articles: (1) full-text available; (2) participants were adults 18 years of age or older; (3) studies had to report use of social network analysis (i.e., social network mapping, assessment of network structure and properties, or analysis of network members); and (4) studies had to report on the actual or proposed development, implementation, evaluation, and/or dissemination of a health behavior intervention. Articles were excluded if (1) social networks were mentioned, but types of analysis were not

reported; (2) the primary focus was social support, peer support, social capital, or other related topics, but did not report a SNA; (3) the utilization of social networks was only included as a recruitment strategy (i.e., peer recommendation for study inclusion); (4) the study included adult participants, but the purpose of the health behavior intervention was to impact the health of individuals under 18; (5) the article was a review, commentary, book, dissertation or conference proceeding. Articles that utilized SNA, but focused on health professional, health systems, and health organization networks (as opposed to individual networks), were also excluded. While we didn' include review articles as individual studies in our review, we used the reviews from our search to identify relevant and eligible articles in the references, to ensure that we were comprehensive in our search (see Figure 1).

A data extraction sheet was developed by the authors, tested on five articles, and further refined before use with all articles. The final sample of 52 articles (representing 46 studies) were characterized by sample (e.g., age distribution, race and ethnic distribution, location), disease or health behavior, type of SNA applications and network measures, network strategies (e.g. induction, alteration), use of behavior change theory, and purpose of study (i.e., implementation, dissemination). Because of the high heterogeneity between studies on disease area and study design, studies were not rated on the quality of methodological rigor.

Results

The final qualitative synthesis includes 52 articles representing a diverse range of interventions informed by SNA. Health topics targeted for intervention varied from cancer screening and survivorship (Luque, Opoku, Ferris, & Guevara Condorhuaman, 2016; Owen, Curran, Bantum, & Hanneman, 2016; Zhao et al., 2014), to latrine ownership (Shakya, Christakis, & Fowler, 2014). The two most common health topics represented in this review were sexual health, particularly HIV prevention, care, and treatment (n=17), and smoking cessation (n=7). Most articles (n=35) were published from 2013-2016, with fewer published in earlier years (14 from 2009-2012 and three from 2005-2008). We present our results below across four broad categories: Setting, Methodology, Application of SNA to inform interventions, and Theory. See Table 1 for detailed results across categories.

Setting

More than half of the intervention articles were designed for a United States context (n=28). Several of the articles were conducted amongst sub-populations across and within cities and regions (e.g., Li and colleagues' 2012 sociometric study of heroine and cocaine users across all of Hartford, Connecticut), while others focused on specific institutions and organizations in the U.S. (e.g., Negrón and colleagues' 2014 mixed methods network study across two Catholic parishes in the Northeast).

The remaining articles were conducted outside of the U.S.: eight in Asia (4 in India, 2 in Bangladesh, and one each in Thailand and China), three in Europe (Hungary/Russia, Italy, Northern Ireland), three in Africa (one each in Kenya, Mali, and Uganda), and one in South America (Peru).

Lastly, internet-mediated networks (n=12) were sometimes but not always based within a specified geographical boundary. As mentioned above, Cobb et al. (2016) recruited 9,042 adult U.S. smokers via Facebook advertising. Other online network interventions were not bound by geography and captured all users regardless of country or region. See Tables 2 and 3 for full results.

Methodology

The majority of articles represented in this review (n=39) were quantitative studies. However, thirteen articles included a qualitative component along with SNA, thus using mixed methods. For example, Weeks and colleagues (2009) used mixed methods to conduct both formative research and longitudinal outcome evaluation, with the inclusion of an ethnographic process evaluation, to examine networks of drug use and harm reduction among peer health advocates and contact referrals. Only five studies used a RCT design to test the effectiveness of the network-based intervention (Amirkhanian et al., 2015; Lakon et al., 2016; Tobin, Kuramoto, Davey-Rothwell, & Latkin, 2011; Young et al., 2014). Across all studies, sample sizes ranged from 29 to 107,000 participants (median = 409).

Data collection on networks and on health behavior outcomes were characterized as cross-sectional and/or longitudinal. Articles commonly collected both network and outcome data cross-sectionally (n=21), and some collected network and outcome data longitudinally (n=19). Three studies collected network data cross-sectionally and outcome data longitudinally. For example, Aiello and colleagues (2016) examined the spread of influenza and other respiratory infections through networks of university students living in residence halls. Nine articles collected data only on networks and not on behavioral outcomes (n= 7 cross-sectional and n= 2 longitudinal).

The majority of articles (n=27) were from partial network studies (i.e., egocentric or personal network data collection). Fewer (n=7) reported being whole network studies (i.e., sociocentric analyses or sociometric data collection). One article (Li et al., 2012) reported conducting both egocentric and sociometric network analyses to test the diffusion of their intervention amongst active drug users.

Notably, 12 of the articles in our review were conducted amongst online networks, meaning that they were fully or partially delivered through the Internet. For example, Cobb et al. (2016) used Facebook to deliver an online application for smoking cessation. Lakon et al (2016) randomized eight networks of adult smokers to a Twitter-based smoking cessation intervention called "Tweet2Quit", and referred to each of the eight online networks as a sociometric network. The authors were able to analyze engagement with the intervention by how they communicated with one another on social media.

A few articles did not classify the network data as either whole, partial, or online, but used other descriptors (e.g., "hidden networks) to classify the analyses. Holloway, Rice, and Kipke (2014) described their HIV prevention study among 526 young men who have sex with men (YMSM) in California as being a "venue-based network analysis" because they generated matrices at different thresholds of person sharing based on commercial venues that participants reported attending. This approach conceptualizes social networks

differently because researchers collected data on venues where subjects exhibit social behavior, but did not directly ask about person-to-person ties. Similarly, Little and colleagues (2014) generated social network data in their HIV transmission study in San Diego, California, USA by not asking participants directly about their sexual and social contacts, but rather used HIV-1 *pol* sequences to infer partial local transmission networks.

Over 100 different network measures were reported. The most commonly described measures were *network density*, the number of connections in the network reported as a fraction of the total links possible (n=23; Valente, 2010), *network size*, the number of individuals or actors in a network (n=15; Valente, 2010), and *degree centrality*, the number of connections or ties an individual sends or receives (n=9; Freeman, 1978). Importantly, several articles have developed newer network measures such as *network stability* (McFadden, Bouris, Voisin, Glick, & Schneider, 2014) and *network turnover* (Costenbader, Astone, & Latkin, 2006), which account for change over time in networks, rather than assume static networks. Tables 1–3 provide complete results.

Application of SNA to Inform Interventions

Two categories emerged when organizing the articles in this review: those that *applied* the SNA to a new or existing intervention (n=20; see Table 2) and those that *proposed* application of SNA to inform behavioral interventions (n=33; see Table 3). One article was categorized as both 'Proposed' *and* 'Applied' (Lorway et al., 2010). This study, conducted in three cities in southern India, collected sexual network data of subjects to enhance an existing intervention, and authors proposed additional intervention implications that might stem from the SNA findings.

We also categorized articles based on which intervention stage(s) that SNA was used to inform: 1) design, 2) implementation, 3) dissemination, and/or 4) sustainability. These stages often overlap and are iterative, but for purposes of this review, it was important to understand what aspects of the intervention were most strongly informed by SNA. Most articles (n=47) used or proposed utilization of SNA to inform intervention design. For example Owen and colleagues (2016) suggest that increasing participant interaction with 'others like me' is one strategy for maximizing the dose of technology-based interventions. Fewer articles described using SNA to inform intervention implementation (n=9), dissemination (n=9), or sustainability (n=8). A few articles described multiple opportunities across intervention development and implementation for applying SNA findings. For example, McFadden and colleagues (2014) conducted a network study where they used network diagrams (sociograms) to generate sexual contact networks for young black MSM. They concluded that their findings held implications not only for interventions to be designed to leverage the networks of young black MSM, but also that doing so could enhance sustainability.

Articles that applied SNA (n=20) were also categorized by type of network intervention strategies used. Many articles (n=16) used induction strategies to activate interactions between network members. In one study (Lorway et al., 2010) participants reported recent sexual partners as part of an intervention to map and prevent HIV transmission. Fewer articles (n=6) used alteration strategies to change the structure of social networks (e.g. adding nodes or links). Other strategies included identification of individuals (n=7) based on

certain network characteristics (e.g. seeds, bridges, or isolates), and segmentation (n=5) or clustering of networks based on characteristics or position. For example, Amirkhanian and colleagues (2015) identified network members with high sociometric scores to serve as information exchange channels with others in the network. Table 2 provides a complete list of network intervention strategies.

Theory

We documented whether articles explicitly defined SNA or gave any mention to *social network theory* (Valente & Pitts, 2017; Erikson & Occhiuto, 2017; Pescosolido & Levy, 2002). The majority of the articles did not define SNA (n=40), and only five articles in this review made explicit mention of social network theory. Given the low utilization of social network theory, we also documented whether and which other health behavioral theories and/or theoretical constructs were used to inform SNA and network interventions. Of the theories mentioned, *Strength of Weak Ties* (Granovetter, 1973) and *Diffusion of Innovations* (Rogers, 1995) were most common, both mentioned in 13 articles. Many articles (n=19) were not informed by theory. See Tables 2 and 3 for full results.

Discussion

To our knowledge this is first study to systematically examine how SNA is being used to inform health behavior interventions among adults. We found a diverse range of populations, settings, and behavioral health topics represented, including prevention, screening, and survivorship. Sexual health and HIV prevention research was the most common focus, followed by tobacco control and smoking cessation. The overwhelming majority of the articles were recent (2013-2016), indicating the burgeoning growth of this field. In terms of setting and population, we found that just over half of the articles focused on the U.S. context, representing a range of cities, regions, and organizations within the U.S. In the global context, areas that were more commonly represented included Asia, Europe, and Africa. While it is promising that a range of settings were represented, it will be important for the field to understand whether there are key differences and similarities found with respect to application of SNA within specific contexts and settings for informing interventions. Furthermore, though there are a growing number of studies specifically focused on HIV, the heterogeneity in topics and settings in the field makes it challenging to make recommendations on how best to apply SNA to interventions within specific behavioral health domains.

Our findings also indicate that while SNA research has grown in recent years, many researchers are not systematically using this work to inform and advance interventions, which we assert is an important lost opportunity. Of all the articles we identified over the 12-year period, only 52 clearly made any link between SNA and intervention development based on the inclusion criteria we used. And among the 52 articles, we found that 38% of articles applied SNA to inform some aspects interventions, rather than propose future application of SNA. In addition, the overwhelming majority of articles (47 of 52) used or proposed utilization of SNA to inform intervention *design*. Valente (2015) has highlighted SNA as an important tool with which to explore the relationships and interests among

networks in developing and determining the most appropriate type of network intervention. During the program development and needs assessment phase, SNA can also provide strategies to consider the social context of program delivery, appropriate methods and communication needs, and identify particular change agents and opinion leaders in the network to focus on (Valente, Palinkas, et al., 2015; Latkin & Knowlton, 2015; Perkins, Subramanian, & Christakis, 2015). Valente and colleagues (2012) describe four strategies for network interventions: 1) identifying individuals who are selected on the basis of a network property, such as 'opinion leaders' in a network; 2) segmentation, where the intervention is directed toward certain segments or groups of people in the population; 3) induction, activation of new interactions between people as links in a network; and 4) alteration, in which interventions change the existing network. In our review, while a number of articles used induction strategies to activate interactions between network members, it was sometimes difficult to categorize interventions according to these strategies given the information reported. We encourage researchers to use these categories to be more explicit about their network intervention approaches. It was also challenging to determine whether interventions informed by SNA were more effective than those that were not, given that only five articles were RCTs that explicitly tested this. Though results have been promising (Latkin & Knowlton, 2015), this is an important area for future research to address.

With the growing literature on dissemination and implementation science, there has been increased recognition of the value of using SNA to inform research and practice in the dissemination and implementation of evidence-based interventions and policies. However, only a small group of articles informed intervention implementation, dissemination or adoption, and sustainability. As researchers move their interventions towards real-world settings, particularly those with more limited resources, SNA may be a critical tool to inform this work (Kim et al., 2015; Luke et al., 2010; Luke et al., 2013; Perkins et al., 2015; Valente, Dyal, Chu, Wipfli, & Fujimoto, 2015). Specifically, there is evidence that network-informed targeting could enhance adoption and efficacy without increasing the number of individuals targeted or the amount of resources used. For example, Kim et al. (2015) found targeting the friends of randomly selected individuals produced greater population-level adoption and health knowledge of a nutritional intervention than targeting random or highly connected individual. Collecting network data during program implementation may also allow interventionists to assess the network impact and make adjustments if necessary. Network characteristics such as centralization, isolates, density, and group cohesion have the potential to identify groups or individuals not receiving the intervention as intended (Gesell, Barkin, & Valente, 2013; Valente, Palinkas, et al., 2015). In one study, Gesell and colleagues used the Social Network Diagnostic Tool to systematically monitor group programs during implementation to guide program activities and build new networks (Gesell et al., 2013). By monitoring how social ties and structure change during program implementation, network diagnostics and data can increase network connectivity and accelerate program diffusion (Gesell et al., 2013). Additionally, network analysis and network mapping are strategies that can be used to identify the continuation of power structures, networks, program champions, and resources in communities that can potentially impact the sustainability of interventions (Valente, Palinkas, et al., 2015).

The majority of articles represented in this review (n=39) were quantitative studies, consistent with SNA which is typically quantitative in nature. However, 13 of the articles included a qualitative component along with SNA, thus incorporating a mixed methods approach. For example, in-depth interviews were used to helped to provide more context for the network centrality and homophily descriptors (Weeks et al., 2009). This approach of contextualizing quantitative SNA data using qualitative data is a promising approach for future researchers to explore, particularly as SNA is more explicitly used to guide different aspects and phases of the intervention process. We found that most studies collected both network and outcomes data cross-sectionally (n=21) and longitudinally (n=19), and we encourage researchers to continue to collect both networks and behavioral data longitudinally given that both are dynamic and likely change over time (particularly since interventions might alter networks).

We also found that most articles used partial networks (e.g., egocentric or personal network data collection), and very few articles were based on whole network studies (e.g., sociocentric analyses or sociometric data collection). This may reflect the reality that it can be challenging and resource-intensive to access whole network data, but we encourage researchers to be explicit in how they obtain network data. Egocentric data can be used to understand whether people engaging in certain behaviors are more likely to have close network members who also engage in those behaviors (Valente, 2010); this type of analysis can capture social influence, social support, and access to resources by measuring the extent to which one's network engages in a behavior (Valente, 2010). Sociometric data, which focus on sets of individuals, such as communities, classrooms, or workplaces, and the social ties among them in these settings (Borgatti, Everett, & Johnson, 2013; Latkin & Knowlton, 2015) is ideal for assessing the collective dimension of social ties or web of relationships (Valente, 2010). This level of analysis is especially useful for studying changes in network structure over time, concentration of power, flow of information or resources, and opportunities to target opinion leaders.

Additionally, the use of SNA among online networks highlights an emerging area in which reporting and understanding network bounds should be further developed. mHealth and eHealth technologies may also be useful strategies to enhance completion of network data collection and tracking over time (Valente, Palinkas, et al., 2015), particularly for sociometric networks. Using 'found' data, existing or automated data collected for purposes other than network research (Timmins, Green, Radley, Morris, & Pearce, 2018), may also provide useful opportunities for examining network data that are less resource intensive, including geospatial data through web mapping platforms (Bethlehem et al., 2014) and social media data from existing platforms (Hingle et al., 2013; Nguyen et al., 2016). Online technologies may enhance network data collection by allowing individuals to visualize their social networks (Kennedy et al., 2018), which may also help encourage participation and minimize missing data.

Across studies, we found over 100 different network measures were reported, likely with some overlap in intent and interpretation. The most commonly described measures were network density, size, and degree centrality. In order to increase the generalizability and reproducibility of findings in applying SNA in the context of intervention, it will be

important for researchers to coalesce around agreed language, terminology, and measures. Presently, it is difficult to make cross-study comparisons and conclusions given the tremendous heterogeneity of terms and measures. The field may want to determine what key components of networks should be measured and reported in SNA studies. This will facilitate greater consistency in reporting SNA data and network descriptions. Very few studies assessed network measures such as network stability (McFadden et al., 2014) and network turnover (Costenbader et al., 2006), which account for change over time in networks. We encourage future research to test more dynamic network measures.

Lastly, we also documented whether studies explicitly defined SNA or gave any mention to social network theory. The majority of the studies did not define SNA (n=40). While SNA has developed across varying disciplines and is only recently been applied in the context of public health, we encourage researchers to be more clear in defining SNA, building off of current definitions in the field (Valente, 2015), and be more explicit when they are conducting SNA. This might promote the adoption and use of SNA and help build a more clearly defined and generalizable literature through use of common definitions, measures, and assumptions. Interestingly, discussions of theory were largely absent in this literature; only five articles explicitly described social network theory in informing their work and 62% used other behavioral theories like Strength of Weak Ties or Diffusion of Innovations. We encourage researchers in this area to be explicit about the theoretical foundations and assumptions guiding and underlying their SNA. Researchers can facilitate advancement of the field by being clear about which intervention components are theory-driven, which network theories and health behavior theories were applied, and whether anything was done to integrate them.

There are several limitations that should be noted. First, of the articles categorized as proposed interventions, there may be recent or current efforts to develop those proposed interventions that had not yet appeared in the published literature during our search, and as such, we may have missed more recently published articles that had intervention implications. Although we conducted an extensive literature review using a wide variety of SNA terms to capture relevant articles, it is possible that some articles may have not been identified. Our decision to include only studies that reported SNA (i.e., network mapping, analysis of network structure or network members) may have excluded studies that conducted network analyses, but were not labeled as such or were not presented in the abstract. We also used articles as the unit for this review, instead of studies (e.g., we had 52 articles representing 46 studies). We took this approach because we found that the analyses and intervention implications conducted within the larger study differed substantially enough across articles that it made sense to present separately. Additionally, while SNA-informed interventions show promise, it is important to note that there can also be challenges with implementing them, as they are often complex and resource-intensive in understanding the social network, and typically require high motivation and engagement of social network members (Wang, Brown, Shen, & Tucker, 2011). Finally, it is important to note that there have been some critiques of the analytical approaches used in SNA (Lyons, 2011), related in part to a lack of statistical theory capable of handling changes and structures unique to social networks (VanderWeele, Ogburn, & Tchetgen Tchetgen, 2012), indicating the need for further methodological and analytical advances in this area.

Despite these limitations, this is the first systematic review that has examined how SNA is being applied to inform health behavior interventions among adults, and followed rigorous and recommended guidelines for systematic reviews. Given our focus on adults and behavioral interventions, we encourage researchers to systematically examine these issues among adolescent/youth populations, and with respect to structural interventions where networks are examined at the organizational, systems, community, state, and country level as well.

Given the nascent and heterogeneous state of the literature in this area, it is challenging to make summaive findings at this point based on health behavior/health outcomes, network measures used, study designs employed, and settings in which this work has been applied. However, we conclude that this is an important opportunity for the field to coalesce on terminology, measures, and theoretical frameworks in this area, and have highlighted priority areas for researchers in how to do so to advance work on the application of SNAs to the design, dissemination, implementation and sustainability of behavioral interventions.

Acknowledgements

References

Aiello AE, Simanek AM, Eisenberg MC, Walsh AR, Davis B, Volz E, … Monto AS (2016). Design and methods of a social network isolation study for reducing respiratory infection transmission: The eX-FLU cluster randomized trial. Epidemics, 15, 38–55. doi:10.1016/j.epidem.2016.01.001 [PubMed: 27266848]

Alexander C, Piazza M, Mekos D, & Valente T (2001). Peers, schools, and adolescent cigarette smoking. Journal of Adolescent Health, 29(1), 22–30. doi:10.1016/S1054-139X(01)00210-5

Amirkhanian YA, Kelly JA, Takacs J, McAuliffe TL, Kuznetsova AV, Toth TP, … Meylakhs A (2015). Effects of a Social Network HIV/STD Prevention Intervention for Men Who Have Sex with Men in Russia and Hungary: A Randomized Controlled Trial. AIDS (London, England), 29(5), 583–593. doi:10.1097/QAD.0000000000000558

Bailey SL, Ouellet LJ, Mackesy-Amiti ME, Golub ET, Hagan H, Hudson SM, … Garfein RS (2007). Perceived risk, peer influences, and injection partner type predict receptive syringe sharing among young adult injection drug users in five U.S. cities. Drug and Alcohol Dependence, 91, S18–S29. doi:10.1016/j.drugalcdep.2007.02.014 [PubMed: 17434267]

Barnett NP, Ott MQ, Rogers ML, Loxley M, Linkletter C, & Clark MA (2014). Peer associations for substance use and exercise in a college student social network. Health Psychology, 33(10), 1134. [PubMed: 24364375]

Berkman LF, & Glass T (2000). Social integration, social networks, social support, and health *Social epidemiology* (pp. 137–173). New York: Oxford University Press.

Berkman LF, Glass T, Brissette I, & Seeman TE (2000). From social integration to health: Durkheim in the new millennium. Social Science & Medicine, 51(6), 843–857. doi:10.1016/S0277-9536(00)00065-4 [PubMed: 10972429]

Berkman LF, Leo-Summers L, & Horwitz RI (1992). Emotional support and survival after myocardial infarction: A prospective, population-based study of the elderly. Annals of Internal Medicine, 117(12), 1003–1009. doi:10.7326/0003-4819-117-12-1003 [PubMed: 1443968]

Berkman LF, & Syme SL (1979). Social Networks, Host Resistance, and Mortality: A Nine-Year Follow-up Study of Alameda County Residents. American Journal of Epidemiology, 109, 186–204. doi:10.1093/aje/kwx103 [PubMed: 425958]

Bethlehem JR, Mackenbach JD, Ben-Rebah M, Compernolle S, Glonti K, Bárdos H, … Lakerveld J (2014). The SPOTLIGHT virtual audit tool: a valid and reliable tool to assess obesogenic characteristics of the built environment. International Journal of Health Geographics, 13, 52. doi:10.1186/1476-072X-13-52 [PubMed: 25515179]

Bohnert ASB, Bradshaw CP, & Latkin CA (2009). A Social Network Perspective on Heroin and Cocaine Use Among Adults: Evidence of Bidirectional Influences. Addiction (Abingdon, England), 104(7), 1210–1218. doi:10.1111/j.1360-0443.2009.02615.x

Booth RE, Lehman WEK, Latkin CA, Dvoryak S, Brewster JT, Royer MS, & Sinitsyna L (2011). Individual and Network Interventions With Injection Drug Users in 5 Ukraine Cities. American Journal of Public Health, 101(2), 336–343. doi:10.2105/AJPH.2009.172304 [PubMed: 20395584]

Borgatti SP, Everett MG, & Johnson JC (2013). Analyzing Social Networks: SAGE.

Bullers S, Cooper ML, & Russell M (2001). Social network drinking and adult alcohol involvement: A longitudinal exploration of the direction of influence. Addictive Behaviors, 26(2), 181–199. doi:10.1016/S0306-4603(00)00099-X [PubMed: 11316376]

Chambers D, Wilson P, Thompson C, & Harden M (2012). Social Network Analysis in Healthcare Settings: A Systematic Scoping Review. PLoS ONE, 7(8), e41911. doi:10.1371/journal.pone.0041911 [PubMed: 22870261]

Choi K-H, Paul J, Ayala G, Boylan R, & Gregorich SE (2013). Experiences of discrimination and their impact on the mental health among African American, Asian and Pacific Islander, and Latino men who have sex with men. American Journal of Public Health, 103(5), 868–874. [PubMed: 23488483]

Christakis NA, & Fowler JH (2007). The Spread of Obesity in a Large Social Network over 32 Years. New England Journal of Medicine, 357(4), 370–379. doi:10.1056/NEJMsa066082

Cobb NK, Jacobs MA, Wileyto P, Valente T, & Graham AL (2016). Diffusion of an Evidence-Based Smoking Cessation Intervention Through Facebook: A Randomized Controlled Trial. American Journal of Public Health, 106(6), 1130–1135. doi:10.2105/ajph.2016.303106 [PubMed: 27077358]

Cohen S, Gottlieb BH, & Underwood LG (2000). Social relationships and health Measuring and intervening in social support (pp. 3–25). New York: Oxford University Press.

Cohen S, & Wills TA (1985). Stress, social support, and the buffering hypothesis. Psychological Bulletin, 98(2), 310–357. doi:10.1037/0033-2909.98.2.310 [PubMed: 3901065]

Costenbader EC, Astone NM, & Latkin CA (2006). The dynamics of injection drug users' personal networks and HIV risk behaviors. Addiction, 101(7), 1003–1013. doi:10.1111/j.1360-0443.2006.01431.x [PubMed: 16771892]

Davey-Rothwell MA, & Latkin CA (2008). An examination of perceived norms and exchanging sex for money or drugs among women injectors in Baltimore, MD, USA. International Journal of STD & AIDS, 19(1), 47–50. doi:10.1258/ijsa.2007.007123 [PubMed: 18275647]

Davey-Rothwell MA, Tobin K, Yang C, Sun CJ, & Latkin CA (2011). Results of a randomized controlled trial of a peer mentor HIV/STI prevention intervention for women over an 18 month follow-up. AIDS Behav, 15(8), 1654–1663. [PubMed: 21468659]

Davey–Rothwell MA, & Latkin CA (2007). HIV–Related Communication and Perceived Norms: An Analysis of the Connection Among Injection Drug Users. AIDS Education and Prevention, 19(4), 298–309. doi:10.1521/aeap.2007.19.4.298 [PubMed: 17685843]

de la Haye K, Robins G, Mohr P, & Wilson C (2010). Obesity-related behaviors in adolescent friendship networks. Social Networks, 32(3), 161–167. doi:10.1016/j.socnet.2009.09.001

de la Haye K, Robins G, Mohr P, & Wilson C (2011). How physical activity shapes, and is shaped by, adolescent friendships. Social Science & Medicine, 73(5), 719–728. doi:10.1016/j.socscimed.2011.06.023 [PubMed: 21802807]

El-Bassel N, Gilbert L, Wu E, & Chang M (2006). A social network profile and HIV risk among men on methadone: do social networks matter? Journal of Urban Health, 83(4), 602–613. [PubMed: 16755389]

Elford J, Bolding G, Davis M, Sherr L, & Hart G (2004). Web-based behavioral surveillance among men who have sex with men: a comparison of online and offline samples in London, UK. JAIDS Journal of Acquired Immune Deficiency Syndromes, 35(4), 421–426. [PubMed: 15097159]

Erikson E, & Occhiuto N (2017). Social Networks and Macrosocial Change. Annual Review of Sociology, 43(1), 229–248. doi:10.1146/annurev-soc-060116-053633

Freeman LC (1978). Centrality in social networks conceptual clarification. Social Networks, 1(3), 215–239. doi:10.1016/0378-8733(78)90021-7

Fujimoto K, Wang P, Ross MW, & Williams ML (2015). Venue-mediated weak ties in multiplex HIV transmission risk networks among drug-using male sex workers and associates. American Journal of Public Health, 105(6), 1128–1135. [PubMed: 25880956]

Fujimoto K, Williams ML, & Ross MW (2013). Venue-based affiliation networks and HIV risk-taking behavior among male sex workers. Sex Transm Dis, 40(6), 453. [PubMed: 23677019]

Fulginiti A, Pahwa R, Frey LM, Rice E, & Brekke JS (2016). What factors influence the decision to share suicidal thoughts? A multilevel social network analysis of disclosure among individuals with serious mental illness. Suicide and Life-Threatening Behavior, 46(4), 398–412. [PubMed: 26511676]

Gayen K, & Raeside R (2010). Social networks and contraception practice of women in rural Bangladesh. Social Science & Medicine, 71(9), 1584–1592. [PubMed: 20869146]

Gesell SB, Barkin SL, & Valente TW (2013). Social network diagnostics: a tool for monitoring group interventions. Implementation Science : IS, 8, 116–116. doi:10.1186/1748-5908-8-116 [PubMed: 24083343]

Granovetter MS (1973). The Strength of Weak Ties. American Journal of Sociology, 78(6), 1360–1380.

Greaney ML, Less FD, White AA, Dayton SF, Riebe D, Blissmer B, … Greene GW (2009). College Students' Barriers and Enablers for Healthful Weight Management: A Qualitative Study. Journal of Nutrition Education and Behavior, 41(4), 281–286. doi:10.1016/j.jneb.2008.04.354 [PubMed: 19508934]

Green HD, Atuyambe L, Ssali S, Ryan GW, & Wagner GJ (2011). Social networks of PLHA in Uganda: implications for mobilizing PLHA as agents for prevention. AIDS Behav, 15(5), 992–1002. [PubMed: 20499149]

Group, N. C. H. S. P. T. (2010). Results of the NIMH collaborative HIV/STD prevention trial of a community popular opinion leader intervention. J Acquir Immune Defic Syndr, 54(2), 204. [PubMed: 20354444]

Hammarström A, Wiklund AF, Lindahl B, Larsson C, & Ahlgren C (2014). Experiences of barriers and facilitators to weight-loss in a diet intervention - a qualitative study of women in Northern Sweden. BMC Women's Health, 14, 59–59. doi:10.1186/1472-6874-14-59 [PubMed: 24739099]

Hingle M, Yoon D, Fowler J, Kobourov S, Schneider ML, Falk D, & Burd R (2013). Collection and Visualization of Dietary Behavior and Reasons for Eating Using Twitter. Journal of Medical Internet Research, 15(6), e125. doi:10.2196/jmir.2613 [PubMed: 23796439]

Holloway IW, Rice E, & Kipke MD (2014). Venue-based Network Analysis to Inform HIV Prevention Efforts Among Young Gay, Bisexual and Other Men Who Have Sex With Men. Prevention science : the official journal of the Society for Prevention Research, 15(3), 419–427. doi:10.1007/s11121-014-0462-6 [PubMed: 24464324]

Hoover MA, Green HD, Bogart LM, Wagner GJ, Mutchler MG, Galvan FH, & McDavitt B (2016). Do people know I'm poz?: factors associated with knowledge of serostatus among HIV-positive African Americans' social network members. AIDS Behav, 20(1), 137–146. [PubMed: 25903505]

House J, Kahn R, Cohen S, & Syme S Measures and concepts of social support Social support and health. 1985: New York: Academic Press.

Hunter RF, McAneney H, Davis M, Tully MA, Valente TW, & Kee F (2015). "Hidden" social networks in behavior change interventions. American Journal of Public Health, 105(3), 513–516. [PubMed: 25602895]

Hurley EA, Warren NE, Doumbia S, & Winch PJ (2014). Exploring the connectedness of rural auxiliary midwives to social networks in Koutiala, Mali. Midwifery, 30(1), 123–129. [PubMed: 23623030]

Jason LA, Light JM, Stevens EB, & Beers K (2014). Dynamic social networks in recovery homes. American journal of community psychology, 53(3–4), 324–334. [PubMed: 24217855]

Jeon KC, & Goodson P (2015). US adolescents' friendship networks and health risk behaviors: a systematic review of studies using social network analysis and Add Health data. PeerJ, 3, e1052. doi:10.7717/peerj.1052 [PubMed: 26157622]

Kawachi I, & Berkman LF (2000). Social Cohesion, Social Capital, and Health In Berkman LF & Kawachi I (Eds.), Social Epidemiology (pp. 174–190). New York: Oxford University Press.

Kelly JA (2004). Popular opinion leaders and HIV prevention peer education: resolving discrepant findings, and implications for the development of effective community programmes. AIDS care, 16(2), 139–150. [PubMed: 14676020]

Kennedy DP, Osilla KC, Hunter SB, Golinelli D, Maksabedian Hernandez E, & Tucker JS (2018). A pilot test of a motivational interviewing social network intervention to reduce substance use among housing first residents. Journal of Substance Abuse Treatment, 86, 36–44. doi:10.1016/j.jsat.2017.12.005 [PubMed: 29415849]

Kim DA, Hwong AR, Stafford D, Hughes DA, O'Malley AJ, Fowler JH, & Christakis NA (2015). A Randomised Controlled Trial of Social Network Targeting to Maximise Population Behaviour Change. Lancet, 386(9989), 145–153. doi:10.1016/S0140-6736(15)60095-2 [PubMed: 25952354]

Knopf A, Agot K, Sidle J, Naanyu V, & Morris M (2015). Reprint of:"This is the medicine:" A Kenyan community responds to a sexual concurrency reduction intervention. Social Science & Medicine, 125, 182–191. [PubMed: 25442970]

Lakon CM, Pechmann C, Wang C, Pan L, Delucchi K, & Prochaska JJ (2016). Mapping Engagement in Twitter-Based Support Networks for Adult Smoking Cessation. American Journal of Public Health, 106(8), 1374–1380. doi:10.2105/AJPH.2016.303256 [PubMed: 27310342]

Latkin CA, Donnell D, Metzger D, Sherman S, Aramrattna A, Davis-Vogel A, … Celentano DD (2009). The efficacy of a network intervention to reduce HIV risk behaviors among drug users and risk partners in Chiang Mai, Thailand and Philadelphia, USA. Soc Sci Med, 68(4), 740–748. doi:10.1016/j.socscimed.2008.11.019 [PubMed: 19070413]

Latkin CA, & Knowlton AR (2015). Social Network Assessments and Interventions for Health Behavior Change: A Critical Review. Behavioral medicine (Washington, D.C.), 41(3), 90–97. doi:10.1080/08964289.2015.1034645

Lewis JA, Manne SL, DuHamel KN, Vickburg SMJ, Bovbjerg DH, Currie V, … Redd WH (2001). Social Support, Intrusive Thoughts, and Quality of Life in Breast Cancer Survivors. Journal of Behavioral Medicine, 24(3), 231–245. doi:10.1023/a:1010714722844 [PubMed: 11436544]

Li J, Weeks MR, Borgatti SP, Clair S, & Dickson-Gomez J (2012). A Social Network Approach to Demonstrate the Diffusion and Change Process of Intervention from Peer Health Advocates to the Drug Using Community. Substance use & misuse, 47(5), 474–490. doi:10.3109/10826084.2012.644097 [PubMed: 22428816]

Little SJ, Kosakovsky Pond SL, Anderson CM, Young JA, Wertheim JO, Mehta SR, … Smith DM (2014). Using HIV Networks to Inform Real Time Prevention Interventions. PLoS ONE, 9(6), e98443. doi:10.1371/journal.pone.0098443 [PubMed: 24901437]

Liu H (2016). Egocentric network and condom use among mid-age female sex workers in China: a multilevel modeling analysis. AIDS Patient Care and STDs, 30(4), 155–165. [PubMed: 27028182]

Lorway R, Shaw SY, Hwang SDH, Reza-Paul S, Pasha A, Wylie JL, … Blanchard JF (2010). From individuals to complex systems: exploring the sexual networks of men who have sex with men in three cities of Karnataka, India. Sexually Transmitted Infections, 86(Suppl 3), iii70–iii78. doi:10.1136/sti.2010.044909 [PubMed: 21098059]

Luke DA, & Harris JK (2007). Network Analysis in Public Health: History, Methods, and Applications. Annual Review of Public Health, 28(1), 69–93. doi:10.1146/annurev.publhealth.28.021406.144132

Luke DA, Harris JK, Shelton S, Allen P, Carothers BJ, & Mueller NB (2010). Systems Analysis of Collaboration in 5 National Tobacco Control Networks. American Journal of Public Health, 100(7), 1290–1297. doi:10.2105/AJPH.2009.184358 [PubMed: 20466950]

Luke DA, Wald LM, Carothers BJ, Bach LE, & Harris JK (2013). Network Influences on Dissemination of Evidence-Based Guidelines in State Tobacco Control Programs. Health

Education & Behavior, 40(1_suppl), 33S–42S. doi:10.1177/1090198113492760 [PubMed: 24084398]

Luque JS, Opoku S, Ferris DG, & Guevara Condorhuaman WS (2016). Social network characteristics and cervical cancer screening among Quechua women in Andean Peru. BMC Public Health, 16, 181. doi:10.1186/s12889-016-2878-3 [PubMed: 26911388]

Lyons R (2011). The spread of evidence-poor medicine via flawed social-network analysis. Statistics, Politics, and Policy, 2(1).

Ma X, Chen G, & Xiao J (2010). Analysis of an online health social network. Paper presented at the Proceedings of the 1st ACM international health informatics symposium.

McFadden RB, Bouris AM, Voisin DR, Glick NR, & Schneider JA (2014). Dynamic social support networks of younger black men who have sex with men with new HIV infection. AIDS care, 26(10), 1275–1282. doi:10.1080/09540121.2014.911807 [PubMed: 24766079]

Michael YL, Berkman LF, Colditz GA, Holmes MD, & Kawachi I (2002). Social networks and health-related quality of life in breast cancer survivors: A prospective study. Journal of Psychosomatic Research, 52(5), 285–293. doi:10.1016/S0022-3999(01)00270-7 [PubMed: 12023125]

Moher D, Liberati A, Tetzlaff J, Altman DG, & The PG (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLOS Medicine, 6(7), e1000097. doi:10.1371/journal.pmed.1000097 [PubMed: 19621072]

Nam S, Redeker N, & Whittemore R (2015). Social networks and future direction for obesity research: a scoping review. Nurs Outlook, 63(3), 299–317. [PubMed: 25982770]

Negrón R, Leyva B, Allen J, Ospino H, Tom L, & Rustan S (2014). Leadership networks in Catholic parishes: Implications for implementation research in health. Social science & medicine (1982), 122, 53–62. doi:10.1016/j.socscimed.2014.10.012 [PubMed: 25441317]

Nguyen QC, Li D, Meng H-W, Kath S, Nsoesie E, Li F, & Wen M (2016). Building a National Neighborhood Dataset From Geotagged Twitter Data for Indicators of Happiness, Diet, and Physical Activity. JMIR Public Health and Surveillance, 2(2), e158. doi:10.2196/publichealth.5869 [PubMed: 27751984]

Owen JE, Curran M, Bantum EOC, & Hanneman R (2016). Characterizing Social Networks and Communication Channels in a Web-Based Peer Support Intervention. Cyberpsychology, Behavior and Social Networking, 19(6), 388–396. doi:10.1089/cyber.2015.0359

Panebianco D, Gallupe O, Carrington PJ, & Colozzi I (2016). Personal support networks, social capital, and risk of relapse among individuals treated for substance use issues. International Journal of Drug Policy, 27, 146–153. [PubMed: 26520237]

Perkins JM, Subramanian SV, & Christakis NA (2015). Social Networks and Health: A Systematic Review of Sociocentric Network Studies in Low- and Middle-Income Countries. Social science & medicine (1982), 125, 60–78. doi:10.1016/j.socscimed.2014.08.019 [PubMed: 25442969]

Pescosolido BA, & Levy JA (2002). The role of social networks in health, illness, disease and healing: the accepting present, the forgotten past, and the dangerous potential for a complacent future Advances in Medical Sociology (Vol. 8, pp. 2–35): Emerald Group Publishing Limited.

Peters PJ, Gay C, Beagle S, Shankar A, Switzer WM, & Hightow-Weidman LB (2014). HIV infection among partners of HIV-infected black men who have sex with Men-North Carolina, 2011–2013. Morbidity and Mortality Weekly Report, 63(5), 90–94. [PubMed: 24500287]

Pollard MS, Tucker JS, Green HD, Kennedy D, & Go M-H (2010). Friendship networks and trajectories of adolescent tobacco use. Addictive Behaviors, 35(7), 678–685. doi:10.1016/j.addbeh.2010.02.013 [PubMed: 20332061]

Powell K, Wilcox J, Clonan A, Bissell P, Preston L, Peacock M, & Holdsworth M (2015). The role of social networks in the development of overweight and obesity among adults: a scoping review. BMC Public Health, 15(1), 996. [PubMed: 26423051]

Rogers EM (1995). Diffusion of Innovations (4 ed.). New York, NY: The Free Press.

Rosenquist JN, Murabito J, Fowler JH, & Christakis NA (2010). THE SPREAD OF ALCOHOL CONSUMPTION BEHAVIOR IN A LARGE SOCIAL NETWORK. Annals of Internal Medicine, 152(7), 426–W141. doi:10.1059/0003-4819-152-7-201004060-00007 [PubMed: 20368648]

Schneider JA, Cornwell B, Ostrow D, Michaels S, Schumm P, Laumann EO, & Friedman S (2013). Network mixing and network influences most linked to HIV infection and risk behavior in the HIV
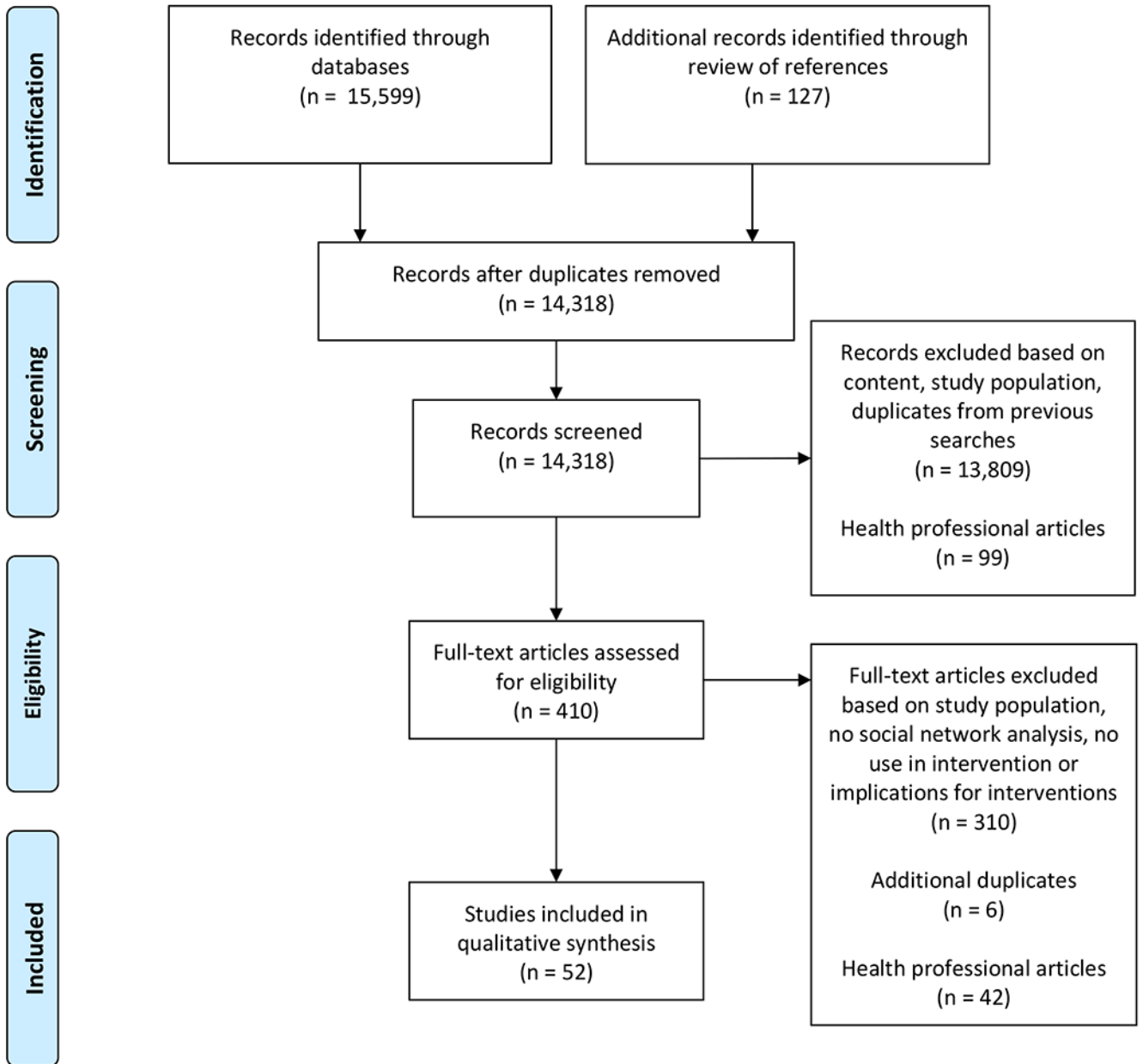
epidemic among black men who have sex with men. American Journal of Public Health, 103(1), e28–e36.

Schneider JA, McFadden RB, Laumann EO, Kumar SP, Gandham SR, & Oruganti G (2012). Candidate change agent identification among men at risk for HIV infection. Social Science & Medicine, 75(7), 1192–1201. [PubMed: 22762951]

Schneider JA, Zhou AN, & Laumann EO (2015). A new HIV prevention network approach: sociometric peer change agent selection. Social Science & Medicine, 125, 192–202. [PubMed: 24518188]

Seo D-C, & Huang Y (2012). Systematic Review of Social Network Analysis in Adolescent Cigarette Smoking Behavior*. Journal of School Health, 82(1), 21–27. doi:10.1111/j.1746-1561.2011.00663.x

Shakya HB, Christakis NA, & Fowler JH (2014). Association Between Social Network Communities and Health Behavior: An Observational Sociocentric Network Study of Latrine Ownership in Rural India. American Journal of Public Health, 104(5), 930–937. doi:10.2105/AJPH.2013.301811 [PubMed: 24625175]

Shaw SY, Shah L, Jolly AM, & Wylie JL (2007). Determinants of injection drug user (IDU) syringe sharing: the relationship between availability of syringes and risk network member characteristics in Winnipeg, Canada. Addiction, 102(10), 1626–1635. doi:10.1111/j.1360-0443.2007.01940.x [PubMed: 17854339]

Sherman SG, Sutcliffe C, Srirojn B, Latkin CA, Aramratanna A, & Celentano DD (2009). Evaluation of a peer network intervention trial among young methamphetamine users in Chiang Mai, Thailand. Social Science & Medicine, 68(1), 69–79. [PubMed: 18986746]

Steptoe A, Shankar A, Demakakos P, & Wardle J (2013). Social isolation, loneliness, and all-cause mortality in older men and women. Proceedings of the National Academy of Sciences, 110(15), 5797–5801. doi:10.1073/pnas.1219686110

Thomson TL, Krebs V, Nemeth JM, Lu B, Peng J, Doogan NJ, … Paskett ED (2016). Social networks and smoking in rural women: Intervention implications. Am J Health Behav, 40(4), 405–415. [PubMed: 27338987]

Timmins KA, Green MA, Radley D, Morris MA, & Pearce J (2018). How has big data contributed to obesity research? A review of the literature. International Journal of Obesity. doi:10.1038/s41366-018-0153-7

Tobin KE, Hua W, Costenbader EC, & Latkin CA (2007). The association between change in social network characteristics and non-fatal overdose: Results from the SHIELD study in Baltimore, MD, USA. Drug and Alcohol Dependence, 87(1), 63–68. [PubMed: 16962254]

Tobin KE, Kuramoto SJ, Davey-Rothwell MA, & Latkin CA (2011). The STEP into Action study: A peer-based, personal risk network-focused HIV prevention intervention with injection drug users in Baltimore, Maryland. Addiction, 106(2), 366–375. [PubMed: 21054614]

Uchino BN, Smith TW, Holt-Lunstad J, Campo R, & Reblin M (2007). Stress and illness Handbook of psychophysiology, 3rd ed (pp. 608–632). New York, NY, US: Cambridge University Press.

Valente TW (2006). Opinion leader interventions in social networks: British Medical Journal Publishing Group.

Valente TW (2010). Social Networks and Health: Models, Methods, and Applications. New York: Oxford University Pres.

Valente TW (2012). Network Interventions. Science, 337(6090), 49–53. doi:10.1126/science.1217330 [PubMed: 22767921]

Valente TW (2015). Social Networks and Health Behavior In Glanz K, Rimer B, & Viswanath K (Eds.), Health Behavior: Theory, Research and Practice (5 ed., pp. 205–222). San Francisco, CA: Jossey-Bass.

Valente TW, Dyal SR, Chu K-H, Wipfli H, & Fujimoto K (2015). Diffusion of innovations theory applied to global tobacco control treaty ratification. Social Science & Medicine, 145, 89–97. doi:10.1016/j.socscimed.2015.10.001 [PubMed: 26460508]

Valente TW, Fujimoto K, Chou C-P, & Spruijt-Metz D (2009). Adolescent Affiliations and Adiposity: A Social Network Analysis of Friendships and Obesity. The Journal of adolescent health : official

publication of the Society for Adolescent Medicine, 45(2), 202–204. doi:10.1016/j.jadohealth.2009.01.007 [PubMed: 19628148]

Valente TW, Hoffman BR, Ritt-Olson A, Lichtman K, & Johnson CA (2003). Effects of a Social-Network Method for Group Assignment Strategies on Peer-Led Tobacco Prevention Programs in Schools. American Journal of Public Health, 93(11), 1837–1843. doi:10.2105/ajph.93.11.1837 [PubMed: 14600050]

Valente TW, Palinkas LA, Czaja S, Chu K-H, & Brown CH (2015). Social Network Analysis for Program Implementation. PLoS ONE, 10(6), e0131712. doi:10.1371/journal.pone.0131712 [PubMed: 26110842]

Valente TW, & Pitts SR (2017). An Appraisal of Social Network Theory and Analysis as Applied to Public Health: Challenges and Opportunities. Annual Review of Public Health, 38(1), 103–118. doi:10.1146/annurev-publhealth-031816-044528

Valente TW, & Rogers EM (1995). The Origins and Development of the Diffusion of Innovations Paradigm as an Example of Scientific Growth. Science Communication, 16(3), 242–273. doi:10.1177/1075547095016003002 [PubMed: 12319357]

Valente TW, Unger JB, Ritt-Olson A, Cen SY, & Anderson Johnson C (2006). The interaction of curriculum type and implementation method on 1-year smoking outcomes in a school-based prevention program. Health Education Research, 21(3), 315–324. doi:10.1093/her/cyl002 [PubMed: 16531503]

VanderWeele TJ, Ogburn EL, & Tchetgen Tchetgen EJ (2012). Why and When "Flawed" Social Network Analyses Still Yield Valid Tests of no Contagion. Statistics, Politics, and Policy, 3(1), 2151–1050. doi:10.1515/2151-7509.1050

Veinot TC, Caldwell E, Loveluck J, Arnold MP, & Bauermeister J (2016). HIV testing behavior and social network characteristics and functions among young men who have sex with men (YMSM) in metropolitan Detroit. AIDS Behav, 20(11), 2739–2761. [PubMed: 26837634]

Vogt TM, Mullooly JP, Ernst D, Pope CR, & Hollis JF (1992). Social networks as predictors of ischemic heart disease, cancer, stroke and hypertension: Incidence, survival and mortality. Journal of Clinical Epidemiology, 45(6), 659–666. doi:10.1016/0895-4356(92)90138-D [PubMed: 1607905]

Wagner GJ, Bogart LM, Klein DJ, Green HD, Mutchler MG, McDavitt B, & Hilliard C (2016). Association of internalized and social network level HIV stigma with high-risk condomless sex among HIV-positive African American men. Arch Sex Behav, 45(6), 1347–1355. [PubMed: 26718361]

Wang K, Brown K, Shen S-Y, & Tucker J (2011). Social network-based interventions to promote condom use: a systematic review. AIDS Behav, 15(7), 1298. [PubMed: 21811843]

Weeks MR, Convey M, Dickson-Gomez J, Li J, Radda K, Martinez M, & Robles E (2009). Changing Drug Users' Risk Environments: Peer Health Advocates as Multi-level Community Change Agents. American journal of community psychology, 43(3–4), 330–344. doi:10.1007/s10464-009-9234-z [PubMed: 19326208]

Wong Y-LI, Matejkowski J, & Lee S (2011). Social integration of people with serious mental illness: Network transactions and satisfaction. J Behav Health Serv Res, 38(1), 51–67. [PubMed: 20052620]

Young SD, Holloway I, Jaganath D, Rice E, Westmoreland D, & Coates T (2014). Project HOPE: Online Social Network Changes in an HIV Prevention Randomized Controlled Trial for African American and Latino Men Who Have Sex With Men. American Journal of Public Health, 104(9), 1707–1712. doi:10.2105/AJPH.2014.301992 [PubMed: 25033137]

Zhang M, & Yang CC (2015). Using content and network analysis to understand the social support exchange patterns and user behaviors of an online smoking cessation intervention program. Journal of the Association for Information Science and Technology, 66(3), 564–575.

Zhao K, Yen J, Greer G, Qiu B, Mitra P, & Portier K (2014). Finding influential users of online health communities: a new metric based on sentiment influence. Journal of the American Medical Informatics Association : JAMIA, 21(e2), e212–e218. doi:10.1136/amiajnl-2013-002282 [PubMed: 24449805]

Research Highlights:

- Interest in applying social network analysis (SNA) in public health is growing.

- We sought to understand the use of SNA to inform behavioral interventions for adults.

- Researchers are not commonly using SNA methods or theory to inform interventions.

- The majority of studies in our review used SNA to inform intervention design.

- The field must coalesce on SNA terminology, measures, and theoretical frameworks.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Identification

Screening

Eligibility

Included

Records identified through databases
(n = 15,599)

Additional records identified through review of references
(n = 127)

Records after duplicates removed
(n = 14,318)

Records screened
(n = 14,318)

Records excluded based on content, study population, duplicates from previous searches
(n = 13,809)

Health professional articles
(n = 99)

Full-text articles assessed for eligibility
(n = 410)

Full-text articles excluded based on study population, no social network analysis, no use in intervention or implications for interventions
(n = 310)

Additional duplicates
(n = 6)

Health professional articles
(n = 42)

Studies included in qualitative synthesis
(n = 52)

Figure 1.
PRISMA Flow Diagram

Table 1.

Summary Descriptives of 52 Articles

Publication Year:

• 2005-2008: 3

• 2009-2012: 14

• 2013-2016: 35

Sample Country/Location:

• Bangladesh: 2

• China: 1

• Hungary: 1

• India: 4

• Italy: 1

• Kenya: 1

• Mali: 1

• Northern Ireland: 1

• Peru: 1

• Russia: 1

• Thailand: 1

• Uganda: 1

• USA: 28

• Online: 12

Health Topic:

• Cancer: 2

• Drug use and HIV prevention: 5

• Exercise and obesity prevention: 3

• Health Promotion: 1

• HIV (prevention, care, treatment): 17

• HIV/STD prevention: 4

• Influenza/respiratory infections: 1

• Latrine ownership: 1

• Mental health/suicide prevention: 2

• Mobile/Electronic Health (mHealth/eHealth): 2

• Obstetric, Maternal, Neonatal, Reproductive Health: 3

• Smoking cessation: 7

• Substance use-related: 4

Applied vs. Potential/Proposed Intervention Implications:

• Applied: 19

• Potential/Proposed: 32

• Both: 1

Article Mentions Social Network Theory:

- Yes: 5
- No: 47

Article Defines Social Network Analysis (SNA):

- Yes: 12
- No: 40

Theories Informing SNA:

- AIDS Risk Reduction Model: 1
- Behavioral Economic Theory: 1
- Cognitive Dissonance Theory: 1
- Diffusion of Innovations: 13
- Dynamic Social Impact Theory: 1
- Focus Theory of Normative Conduct: 1
- Fundamental Cause Theory: 1
- Health Belief Model: 1
- HIV Stigma Theory: 1
- Ideational Change Theory: 1
- Minority Stress Model: 1
- Social Capital Theory: 3
- Social Cognitive Theory/Social Learning Theory: 11
- Social Ecological Model: 1
- Social Exchange Theory: 1
- Social Identity Theory: 3
- Social Influence Theory: 3
- Social Network Theory: 5
- Social Support Theory: 6
- Social Systems Theory: 1
- Strength of Weak Ties: 13
- Stress/Coping Theory: 2
- Theory of Duality of Persons and Groups: 1
- Theory of Planned Behavior/Theory of Reasoned Action: 7
- Transtheoretical Model/Stages of Change: 3
- None specified: 19

Common Social Network Measures[1]:

- Density: 23
- Network size: 15
- Degree centrality: 9
- Betweenness centrality: 7
- Homophily: 5
- Tie strength: 5

Network Types:

- Whole Network (e.g., Sociocentric, Sociometric, Complete Network): 7

• Partial Network (e.g., Egocentric, Personal Network, Incomplete Network): 27

• Both Whole and Partial: 1

• Both Partial and Other: 1

• Online Networks: 12

• Other (e.g., venue-based network, hidden network, etc.): 4

Overall Study Methods:

• Quantitative: 39

• Mixed Methods: 13

Cross-sectional vs. Longitudinal Network Data:

• Network and Outcomes Data Both Cross-Sectional: 21

• Network Cross-Sectional, Outcomes Longitudinal: 3

• Network Longitudinal, Outcomes Cross-Sectional: 0

• Network and Outcomes Both Longitudinal: 19

• Only Network Data and Cross-Sectional: 7

• Only Network Data and Longitudinal: 2

Network Intervention Strategies [2]***:***

• Identification: 7

• Segmentation: 5

• Induction: 16

• Alteration: 6

Application of SNA to Inform Intervention Design, Dissemination, Implementation, and/or Sustainability [3]***:***

• Design: 47

• Dissemination: 9

• Implementation: 9

• Sustainability: 8

[1] The full list of social network measures can be found in Tables 2 and 3.

[2] Network intervention strategies from Valente (2012) were only applicable to the 20 articles from Table 2 that applied SNA.

[3] Articles could apply SNA to inform more than one of the four categories.

Table 2.

Descriptive topical, methodological and network characteristics from Applied[1] SNA Interventions in the Review (n=20)

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
1	Adams (2015)	**Bangladesh** 933 women who had given birth in the last three months in 5 poor urban settlements in Dhaka, Bangladesh	Maternal care	Social Support Theory Strength of Weak Ties	Network data cross-sectional Quantitative Social networks questionnaire used an egocentric design Data analysis explored associations between maternal/ neonatal health indicators and network characteristics.	Partial network *Density* *Network size* *Tie proximity* *Tie strength*	Alteration	**Informed design** Findings suggest enhancing support networks of poor urban women around pregnancy/ childbirth impacts use of best maternal and neonatal health practices, and may diffuse beyond program.
2	Aiello (2016)	**USA** 590 students in residence halls of public university.	Influenza and respiratory infections	None.	Randomized Control Trial Network data cross-sectional outcome data longitudinal Quantitative Six university residence halls divided into 117 clusters based on factors likely to influence social interactions; clusters randomized to intervention or control. Sub-sample (N = 103) provided smartphone with *iEpi* app that collects data used to geo-locate participants and record data relevant to interactions.	Whole network *Assortativity* *Average Clustering Coefficient* *Betweenness* *Centrality* *Closeness* *In-degree* *Out-degree* *Total degree* *Transitivity*	Segmentation Induction	**Informed design** This is the first study design to overlay a randomized isolation intervention onto a social network populated via chain referral sampling and to prospectively collect data on social interactions. Suggests importance of assessing what role an individual's position in the social network may play in their health behaviors
3	Amirkhanian (2015)	**Russia & Hungary** 626 MSM in 18 networks were enrolled. MSM 'seeds' were identified in community venues (e.g. bars)	HIV/STD prevention	Information Integration Theory Social Cognitive Theory	Randomized Control Trial Network and outcome data longitudinal Quantitative Recruited 18 sociocentric networks of high-risk MSM; randomized networks to receive voluntary HIV/STD testing and counseling alone or a social network intervention, and evaluated impact on sexual risk characteristics and HIV/STD incidence.	Whole network *Betweenness centrality* *Sociometric score*	Identification Induction	**Informed design, dissemination** By training and engaging leaders high in sociometric status and network interconnections to counsel other network members, the intervention likely functioned to strengthen support, skills, and intentions for protective behavior in network.
4	Centola (2010)	**Online** 1528 participants recruited from health-interest websites	Adopting new health behaviors (e.g. registering for an Internet health forum)	Diffusion of Innovations Strength of Weak Ties	Network and outcomes longitudinal Quantitative Participants created online profile with health interests and matched with "health buddies" Participants randomized to a clustered-lattice network or a random network–	Online network *Clustering* *Degree* *Density*	Induction Alteration	**Informed design** Interventions aimed at spreading new health behaviors may try targeting clustered residential networks rather than the casual contact networks–particularly if behaviors to be diffused are highly complex.

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
					distinguished only by structure of networks. Results are from six independent trials, each a matched pair of network condition w/ 12 independent diffusion processes.			
5	Centola (2011)	**Online** 710 participants, recruited from an online fitness program	Exercise; obesity	Diffusion of Innovations Fundamental Cause Theory Strength of Weak Ties	Network and outcomes data longitudinal Quantitative Randomized to social networking communities, in which homophilously structured populations, in which individual factors (gender, age, BMI) were "clustered"; or (ii) randomly mixed, unstructured populations. Participants made decisions about adoption of Internet-based diet diary.	Online network *Homophily*	Induction Alteration	**Informed design, dissemination** Homophily improves adoption of health behavior, and can allow behavior to spread more successfully across a heterogeneous population, providing greater levels of exposure to individuals with diverse health characteristics. These findings may be particularly important for the design of online health communities, where the structure of social relations can be explicitly determined on the basis of individuals' health characteristics
6	Cobb (2016)	**USA Online** 9042 smokers recruited via Facebook advertising	Smoking cessation	Diffusion of Innovations	Network and outcome data longitudinal Quantitative Randomized smoker to 1 of 12 app variants using a factorial design. App variants targeted diffusion components: duration of use, "contagiousness", number of contacts. Primary outcome was the reproductive ratio: number of individuals installing the app divided by the number of a seed participant's Facebook friends.	Online network *Average clustering coefficient* *Betweenness centrality* Count friends (Degree) *Count friends with friends* *Graph transitivity* *Total mutual friend count*	Induction	**Informed design** Viral spread is possible to manipulate within online application for behavior change. Intervention designers should consider the importance of diffusion alongside metrics of efficacy.
7	Davey-Rothwell (2011)	**USA** Baltimore, MD 169 heterosexual women	HIV/STI prevention	Cognitive Dissonance Theory Social Diffusion Theory Social Identity Theory Social Influence Theory Social	Network and outcome data longitudinal Mixed-methods CHAT intervention, a social-network based intervention for women trained to be Peer Mentors. Participants randomized into comparison condition or Peer Mentor condition. Intervention measured changes in: number of sex partners, condom and drug	Partial network *Node attributes*	Identification Induction	**Informed design, dissemination, sustainability** Peer education interventions capitalize on naturally occurring social influence processes and can sustain behaviors for an extended period of time. By taking on the role of Peer Mentor, women lowered their own risk for HIV and STIs. While all of the index participants were women, over

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
				Learning Theory	use, HIV/STI communication among Peer Mentors			half of the network participants were men. Thus, Peer Mentor interventions for women are also an avenue to reach men. In addition, through dissemination of risk reduction resources and information in a social network, norms about risk reduction may prevail.
8	Hunter (2015)	**Northern Ireland** 406 participants from a financial incentive physical activity (PA) behavior change intervention	Workplace physical activity	None.	Network and outcome data longitudinal Quantitative Investigated whether networks were evident in PA intervention, and characteristics and evolution of the network structure. Sensors along footpaths and in gym in workplace. Employees scanned card that logged their activity and facilitated identification of their social networks.	Other (Hidden network) *Degree centrality* *Density* *Jaccard index* *Number of ties* *Triadic census*	Induction	**Informed design, sustainability** Emerging technologies enable unobserved social interactions in behavior change interventions to be objectively measured and monitored.
9	Jason (2014)	**USA** 5 U.S. urban recovery houses (part of a network of substance use recovery homes) 31 total participants.	Alcohol abuse and recovery	Behavioral Economic Theory Social Ecological Model Social Learning Theory Stress/Coping Theory	Network data longitudinal Quantitative Tested model of "social integration" dynamics—formation of trust, confidant relationships— as a function of individuals' range of 12-step activities and time in residence.	Whole network *Out-degree* *Reciprocity* *Transitivity*	Alteration	**Informed dissemination** Approach advanced understanding of recovery house social dynamics that may support abstinence and mediators of abstinence. These relationships could ultimately be predictors of key recovery outcomes
10	Knopf (2015)	**Kenya** 226 Luo adults in Nyanza Province, Kenya Varying study participants throughout 3 research phases.	Sexual concurrency + HIV	Diffusion of Innovations Theory of Reasoned Action/Theory of Planned Behavior	Network data cross-sectional Mixed-methods Know Your Network (KYN) is educational intervention to initiate discussion about partner concurrency. Participants provided egocentric data on sexual partnerships, and study evaluated feasibility and acceptability.	Partial network *Degree distribution*	Induction	**Informed dissemination, implementation, sustainability** Focused on communities rather than individuals to leverage spillover effects that would result from potentially small changes in behavior.
11	Lakon (2016)	**USA Online** 160 smokers in 8 networks were randomized to	Smoking Cessation	None.	Randomized Control Trial Network and outcome data longitudinal Quantitative Interactive Twitter-based	Online network *Average tie strength in a network* *Density*	Segmentation Induction Alteration	**Informed design** Provides insight into how intervention participants' communication patterns and abstinence evolved; informs

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
		Twitter in larger RCT.			intervention ("Tweet2Quit") that included automessaging to encourage tweeting. Examined 8 online social networks, as sociometric networks, including participants and network ties (tweets sent).	*In-degree centrality (individual and average) Number of mutually connected 4-person cliques Number of mutually connected triangles Number of reciprocated ties Proportion of reciprocated ties in a network Sociograms Tie strength*		future research examining social media and smoking cessation.
12	Li (2012)	**USA** Active drug users in Hartford, CT. 112 trained PHAs (Peer Health Advocates) 411 contacts or referrals	Drug use (heroin and cocaine) harm reduction (e.g. HIV prevention)	Diffusion of Innovations Social Learning Theory Strength of Weak Ties	Network and outcome data longitudinal Quantitative The Risk Avoidance Partnership (RAP) tracked network relationships and dynamics in peer intervention. Examined location of PHAs and others in network of drug users, social network structure of participants, intervention diffusion processes, nonlinear change dynamics, effect of social action on the individual and network levels, and social influence patterns within the sociometric network of drug users.	Partial and Whole network *Node attributes Nodes Number of active intervention ties Proximity to active intervention ties Ties (self-reported, peer reported, total)*	Identification Induction	**Informed design** Network analysis of RAP intervention diffusion process demonstrated success of training active drug users as peer interventionist. Trained peer interventionists benefitted by reducing their own risk, and were also empowered to become change agents.
13	Lorway (2010) *NOTE: This study is both Applied and Proposed because based on study findings, it also proposes making changes to the	**India** South India state of Karnataka. 431 individuals from seven-day sexual networks. Regular networks – Data from 334 available for regular sex networks. 48 nodal MSM interviewed.	HIV transmission	None.	Network and outcome data cross-sectional Mixed-methods Sexual network data and surveys collected through larger community-based participatory research project. Collected seven day sexual networks (nodes of sexual networks) and regular sexual networks.	Partial network *Network size Node attributes*	Induction	**Informed design, implementation** Results suggest there is a substantial advantage in both quantifying and qualifying sexual networks. Sexual network diagrams show the non-linear pathways of transmission in relation to the unpredictable patterns of sexual interaction between individuals.

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
	existing intervention							
14	Owen (2016)	**Online** 299 cancer survivors with significant distress using the 12-week health-space.net intervention	mHealth/eHealthCancer	None.	Network and outcome data longitudinal Quantitative Evaluates social network characteristics of four communication channels (discussion board, chat, e-mail, and blog) in a large social networking intervention, predicts membership in online communities, and evaluates whether community membership impacts engagement.	Online network *Average degree Clustering Connectedness Density Path length*	Segmentation	**Informed design, implementation** Results suggest that providing multiple ways in which individuals can interact, and find and connect with "others like me," " is an ideal strategy for maximizing the dose of intervention that can be provided with technology-based interventions.
15	Schneider (2015)	**India** High-risk MSM in Southern India 20 "cruising areas" where MSM congregate 241 study respondents and their MSM contact list members (n = 4991).	HIV prevention	None.	Network data cross-sectional Quantitative Sociometric network analyses. Measured structural positions to select candidate PCAs and assess their characteristicss. Did recruitment, interview and generated communication network; then included network position-based selection and interviews	Whole network *Betweenness centrality Bridging*	Identification Induction	**Informed design, dissemination** Identifying bridges who may be able to diffuse innovation more effectively within high-risk HIV networks is critical.
16	Sherman (2009)	**Thailand** 983 young adults in northern Thailand; ages of 18 and 25.	Methamphetamine use, sexual behaviors, and sexually transmitted infections (STIs)	Diffusion of innovations Social learning theory Social identity theory	Randomized behavioral trial Network data cross-sectional, outcome data longitudinal Mixed methods Conducted 12-month trial comparing efficacy of a peer educator, network-oriented intervention to a best practice, life-skills curriculum. Individual survey and network survey	Partial network *Network size Network composition*	Identification Segmentation Induction	**Informed design, implementation** Peer education, social network intervention was associated with reductions in methamphetamine use and increases in condom use over 12 months. It found parallel and equally significant reductions associated with the life-skills training condition. The study indicates that small group interventions are highly appropriate in reducing risk among young adult Thais.
17	Tobin (2011)	**USA** Baltimore, Maryland 227 Index participants with self-reported	Drug use (heroin and cocaine) harm reduction (including HIV prevention)	Social identity theory	Randomized Control Trial Network data cross-sectional, outcome data longitudinal Quantitative Prospective data collection at 6, 12, and 18 months to assess	Partial network *Diffusion Network size*	Identification Induction	**Informed design, sustainability** Results from the STEP into Action intervention indicate sustained efficacy on reduction of HIV risk behaviors and diffusion of this effect to risk

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
		injection drug use 336 risk network members (RNM) recruited by Index participants			effectiveness of peer-based, personal risk network focused HIV prevention intervention.			network members. Training active IDU to promote HIV prevention with behaviorally risky individuals in their networks is feasible, efficacious and sustainable.
18	Weeks (2009)	**USA** Hartford, Connecticut 367 Peer Health Advocates and Contact Referrals	Drug use harm reduction, including HIV prevention	Diffusion of Innovations Dynamic social impact theory Social Learning/ Social Cognitive Theory Strength of Weak Ties	Network and outcome data longitudinal Mixed-methods The RAP study used an intensive observational design in a single study site with mixed method formative research, an ethnographic process evaluation, a longitudinal mixed method outcome evaluation, and a cross-sectional drug-use community assessment to measure impacts of the RAP interventions on different social levels over time	Partial network *Centrality Homophily*	Identification Induction	**Informed design, implementation, sustainability** The intervention needs an ongoing infusion of new resources, including newly trained PHAs, reinforcement of the infrastructure, to be sustained over an extended period of time. The program utilized the natural network structure and connections among drug users as channels and support for dissemination of relevant prevention materials. Key community resources and intrinsic characteristics of drug user networks were folded into the design and process of health advocacy and prevention intervention.
19	Young (2014)	**USA Online** 105 MSM in Los Angeles county, 16 of whom were peer leaders.	HIV prevention	Diffusion of Innovations	Randomized Control Trial Network and outcome data longitudinal Quantitative The Harnessing Online Peer Education (HOPE) intervention, a 12-week randomized controlled HIV prevention intervention designed to use peer-led Facebook groups to diffuse HIV information to increase testing. Examined the association between changes in online social network structure and HIV prevention and testing among HOPE network participants.	Online network *Average path length Degree centrality Density Distance-based cohesion*	Induction	**Informed design, dissemination** Among racial/ethnic minority MSM, peer-led online social media HIV prevention interventions can increase community cohesion, and these network changes appear to be associated with increased HIV testing.
20	Zhao (2016)	**Online** 71,251 users of Web-based smoking cessation program	Smoking cessation	None.	Network and outcome data longitudinal Quantitative Constructed multirelational network consisting of 4 subnetworks: private messages, message boards, group	Online network *Density In-degree Individual Centrality Jaccard Index Largest strongly*	Segmentation Alteration	**Informed design, implementation** Analyzing centrality using multirelational approach may be useful in improving the effectiveness of health interventions.

#	Author(s) / Year	Population/ Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Strategies[2]	SNA Implications (Intervention Design, Dissemination, Implementation, and/or Sustainability)
					discussions, and blogs and examined structural similarities and dynamics across networks,. Examined role of centrality in influencing abstinence rates.	*connected component (LSCC) Network overlap Number of edges Out-degree Proportion reciprocated Total degree*		

[1] Articles in this review that applied the SNA to a new or existing intervention

[2] Valente (2012) describes four strategies for network interventions: 1) *identifying* individuals on the basis of a network property; 2) *segmentation* of certain groups in the population; 3) *induction* of interactions between nodes in a network; and 4) *alteration* of the existing network

Table 3.

Descriptive topical, methodological and network characteristics from Proposed[1] SNA Interventions in the Review (n=33[2])

#	Author(s)/Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
1	Barnett (2014)	**USA** 129 undergraduates in residence hall of Northeast university	Substance use and exercise	None.	Network and outcome data cross-sectional Quantitative Survey measured alcohol and marijuana use, alcohol-related and exercise. Respondents identified up to 10 people who have been important to them since the start of school year and which lived in their residence hall.	Partial network *Community detection cluster analysis Network autocorrelation modeling*	**Informed design** Social networks on college campuses may be useful in planning prevention programs because social connections have the potential to transmit adaptive or positive health behaviors and/or change maladaptive behaviors.
2	Choi (2013)	**USA** 1196 MSM in Los Angeles, CA.	HIV prevention	Strength of Weak Ties	Network and outcome data cross-sectional Quantitative Described and compared egocentric networks across three racial/ethnic groups of MSM and documented role of network characteristics in determining HIV risk.	Partial network *Density Ego-alter closeness Network size*	**Informed design** Understanding social network characteristics (e.g. ego-alter closeness) and how they influence safer sex peer norms and HIV sexual risk provides valuable starting point for HIV prevention.
3	Cobb (2010)	**Online** QuitNet members who were active during 60-day period, and their ties 7,569 participants with 103,592 connections.	Smoking cessation	Transtheoretical Model / Stages of Change	Network and outcome data longitudinal Quantitative Collected anonymized registration data, web site utilization data, and subsequent recording and changes to quit dates that occurred during 60-day window. Chose symmetric buddy nominations to differentiate the strongly connected core from the densely connected core. Delineated 3 additional subgroups from the weakly connected core: newcomers, integrators, and key players.	Online Network *Betweenness centrality Degree centrality*	**Informed design and implementation** Findings illustrate the potential of innovative social network interventions to enhance behavior changes that can dramatically improve health in the Internet age. Key player analysis illustrated one mechanism of identifying subgroups within large networks for dissemination of information. Future research is needed to characterize network integrators and determine whether increasing their numbers or strengthening their role can effect more efficient behavior change.
4	Costenbader (2006)	**USA** 409 injection drugs users (IDUs) from HIV-intervention study (SHIELD) in Baltimore, MD.	HIV risk behavior	None.	Network and outcome data longitudinal Quantitative Study staff delineated the personal networks of survey respondents at all three times. Used name generator questions to elicit names of people with whom respondent socializes, has sex, does drugs and/or calls upon for material and emotional support.	Partial network *Network density Network turnover (in and out)*	**Informed design** Interventions which work with injectors to supplant their drug-using friends with non-drug-using contacts may be more successful in achieving sustained risk reduction.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
5	El-Bassel (2006)	**USA** 356 men from a methadone maintenance treatment program (MMTP) in NYC.	HIV risk behaviors among drug users	Social Learning Theory Theory of Planned Behavior	Network and outcome data cross-sectional Quantitative Information about participants' social network was elicited using the Social Network and Support Questionnaire for Methadone Patients.	Partial network *Density Gender of alters Network Size Network size of most frequent and recent contacts Number of immediate family alters*	**Informed design** Findings indicate that denser networks may lend themselves to a more efficient spread of HIV prevention messages among this population of men in MMTPs.
6	Fujimoto (2015)	**USA** 387 drug-using male sex workers and their male and female associates in Houston, TX.	HIV prevention	Strength of Weak Ties	Network and outcome data cross-sectional Mixed-methods Interviewed key informants and identified focal participants. Generated analytic sample' to examine the tendency of reciprocity and the effect of homophily on HIV status and sociodemographic and behavioral factors.	Partial network; Other (Venue-based network) *1-mode reciprocated tie effect Homophily effect Venue-mediated tie effect Venue-mediated strong tie effect Venue-mediated weak tie effect*	**Informed design** Structuring interventions to account for the social- and venue-based affiliation network structure of male sex work is more likely to be effective than onesize-fits-all interventions.
7	Fujimoto (2013)	**USA** 208 MSW (Male Sex Workers) affiliated with 15 gay bars and 51 street intersections in Houston, TX.	HIV prevention	None.	Network and outcome data cross-sectional Mixed-methods Examined structural features of venue-based MSWs' affiliation with gay bars and street intersections in relation to sexual behavior and HIV infection. Used Sexual Network Questionnaire and visual representation of affiliation networks were identified using centrality measures and graphs.	Other (Venue-based network) *Degree Centrality Eigenvector centrality Clustering (using a spring-embedding algorithm) Affiliation Exposure*	**Informed design** Suggests new directions in developing networkbased, venuetargeted HIV/AIDS prevention interventions (e.g. a program could increase its impact by targeting the structurally-identified risky venues).
8	Fulginiti (2016)	**USA** 30 adults with schizophrenia, bipolar disorder, or major depressive disorder who nominated 436 social network members	Suicide	Strength of Weak Ties	Network and outcome data cross-sectional Mixed methods Using social network methodology and multilevel modeling, the study examined disclosure practices as well as individual- and relational-level factors that affect decisions to disclose suicidal thoughts.	Partial network *Relational homophily Relationship availability Relationship duration Relationship quality Relationship type*	**Informed design** Improved understanding of disclosure patterns and identification of key disclosure correlates (strength of relationship, availability, homophily) can inform service delivery efforts that facilitate disclosure and create more opportunities for suicide risk management.
9	Gayen (2010)	**Bangladesh** 694 women, who were married, of reproductive age, and had children, from seven villages in rural Bangladesh.	Fertility behavior and use of contraception	Ideational Change Social Interaction (Social Learning and Social Influence) Social Network Theory Strength of Weak	Network and outcome data cross-sectional Quantitative A structured questionnaire used to conduct face-to-face interviews on five domains including sociometric measures. Structural properties analyzed	Whole network *In-degree centrality Out-degree centrality Bonacich's Power Sociograms*	**Informed design** Within these networks, some women are more central than others and have positions of greater influence and power. It is important to examine the characteristics of central people and the network mechanisms by which they influence others.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
				Ties Diffusion of Innovations	included Freeman's degree centrality and Bonacich's Power Index.		
10	Green (2011)	**Uganda** 39 HIV-positive adult clients attending an HIV clinic in Kampala.	HIV prevention advocacy	None.	Network data cross-sectional Quantitative Computer assisted interviews conducted. Perceptions of general social support, peer community support, HIV discrimination, and internalized HIV stigma were assessed.	Partial network *Average degree* *Cliques* *Components* *Density* *Isolates* *Maximum degree*	**Informed design** Diversity in respondents' networks vis-à-vis HIV status suggests that a range of prevention advocacy activities should be built into any network-based intervention.
11	Holloway (2014)	**USA** 526 YMSM in Los Angeles, CA	HIV prevention	Diffusion of Innovations Theory of Duality of Persons and Groups	Network and outcome data cross-sectional Quantitative A venue-based network analysis was used to describe connections among social venues frequented by YMSM in LA. Participants named their "favorite three gay places to socialize", creating the network of venues. Matrices were used to create venue networks at different thresholds of person sharing.	Other/Venue-based network) *Person-sharing thresholds* *Spring embedding*	**Informed design** Venue-based network analysis can inform tailored HIV prevention messaging for YMSM. Targeted delivery of prevention messaging at low-risk centralized venues may lead to widespread diffusion among venue attending YMSM.
12	Hoover (2016)	**USA** 244 HIV-positive African Americans in Los Angeles, CA	HIV disclosure	None.	Network and outcome data cross-sectional Quantitative Interviewer guided participants through adherence and social network measures.	Partial network *Degree centrality* *Density*	**Informed design** Findings may contribute to development of interventions that help develop disclosure strategies to improve health in multiple dimensions (e.g. maximizing social support).
13	Hurley (2014)	**Mali** 29 midwives in Koutiala in southern Mali.	Rural health– auxiliary midwives	None.	Network and outcome data cross-sectional Mixed-methods Social network analyses were conducted among women in 2 villlages. Participants asked about social relationships with their communities.	Whole network *Eigenvector of geodesic distance* *Freeman degree centrality*	**Informed design** Program planners and policy-makers should consider the potential of using midwives to communicate when designing behavioral interventions for women in underserved areas.
14	Little (2014)	**USA** Analyzed HIV-1 *pol* sequences generated over 15 years from 478 recently HIV-1 infected persons and 170 of their HIV-1 infected sexual and social contacts in San Diego, CA.	HIV transmission	None.	Network and outcome data longitudinal Quantitative Analyzed HIV-1 *pol* sequence data to infer a partial local transmission network. A transmission network score (TNS) was developed to estimate the risk of HIV transmission from a newly diagnosed individual to a new partner and target prevention interventions. HIV-1 *pol* sequences generated from	Partial network *Degree (connectivity)* *Density* *Edges* *Out-edges*	**Informed design** TNS provides a new method for estimating transmission risk within a network, and could likely be extended to infer regional transmission networks from the extensive archives of HIV sequence data stored in commercial databases.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
					each participant were used to infer the transmission network.		
15	Liu (2016)	**China** 1,245 mid-age female sex workers (FSWs) and 1300 alters in ego's support networks.	Sex worker condom use	Social Network Theory Theory of Planned Behavior	Network and outcome data cross-sectional Quantitative The Chinese Social Network Questionnaire (CSNQ) was used to capture the social support network of egos.	Partial network *Alter–ego relations Ego–alter ties Sexual network size Supporting network size Tangible and emotional support*	**Informed design** As condoms are more likely to be used among weak ties than strong ties, interventions should target both strong and weak ties so that behavioral changes can be sustained.
16	Luque (2016)	**Peru** 69 surveys with Quechua women who attended two previous campaigns for the CerviCusco outreach screening campaign.	Cervical cancer screening	None.	Network and outcome data cross-sectional Quantitative Each participant (ego) named six other women they knew (alters) and nature of their relationship or tie (family, friend, neighbor, other), residential closeness (within 5 km), length of time known, frequency of communication, topics of conversation, and whether they lent money to the person, provided childcare or helped with transportation. Examined social network characteristics in relation to Pap test receipt.	Partial network *Density Mean betweenness centrality Mean degree centrality*	**Informed dissemination** Social networks are one information channel that might be leveraged to deliver educational and behavioral interventions to increase adherence to screening and follow-up for abnormal findings in rural indigenous communities in Latin American countries.
17	Ma (2010)	**Online** Five months of data collected from more than 107,000 users on an online health social network.	Diet and weight management	Social capital	Network and outcome data longitudinal Quantitative Weigh-in behaviors and weight-change progress was studied for users of FatSecret, an online health social network. User profiles and user friend lists were examined to understand relationships between number of friends, friend attributes, weigh-ins, and weight change.	Online network *Network size Network density*	**Informed design** Results suggest that with support from similar weight users who want to achieve similar weight-change goals, a user of an online health social network is more likely to make progress. Online social network providers should use a variety of mechanisms to encourage users to regularly weigh-in and strengthen social connections.
18	McFadden (2014)	**USA** 14 YBMSM newly diagnosed with HIV - 83 unique sexual contacts named.	HIV care and treatment	Social Cognitive Theory Social Network Theory	Network and outcome data longitudinal Quantitative Interviews conducted by HIV clinic staff. Used participant-aided network diagrams, or sociograms, to assist in network elicitation.	Partial network *Betweenness Constraint Density Network size Network Stability Proportion of SCs disclosed to Proportion of sexual contacts in distinct role categories - (1) family of origin, (2) friend, (3) sex*	**Informed design, sustainability** Interventions that harness the organic support systems of YBMSM to improve health outcomes, particularly related to HIV infection, offer great promise for long-term efficacy with low resource utilization. The support-seeking behavior in this group poses a unique opportunity for intervention wherein a new social confidant to whom the HIV-infected individual has disclosed to could be recruited to provide personal support and health promotion.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
						partner; and (4) other Sociograms	
19	Myneni (2013)	**Online** Database of 16,492 de-identified public messages from QuitNet website.	Smoking cessation	Diffusion Of Innovations Health Belief Model Social Cognitive Theory Transtheoretical Model / Stages of Change	Network data cross-sectional Mixed-methods Messages were used to generate contentbased social networks by representing QuitNet users as nodes, and their communication as edges. Networks were analyzed using network analysis methods to understand contentspecific network patterns.	Online network *Degree Modularity*	**Informed design** Insights into the distribution of key nodes can inform the design of targeted interventions that disseminate information and establish relationships based on the mentee needs and mentor interests.
20	Negrón (2014)	**USA** Two northeast USA Catholic parishes (one with about 450 parishioners and one with congregation of about 600)	Adoption and implementation of evidence-based interventions for health promotion	None.	Network data cross-sectional Mixed-methods After establishing contacts, a list of formal and informal leaders was compiled. Parish leaders were administered roster surveys. Leaders were asked to evaluate their ties to other leaders on a list that they themselves were on.	Other (organizational leadership network) *Betweenness centrality Degree centrality Density Individual degree centrality Network centralization Tie-strength*	**Informed dissemination, implementation, sustainability** Study provides a framework for utilizing SNA to identify key decision-makers for adoption of new programs, program champions who can ensure widespread support, individuals and/or teams charged with program implementation, and key individuals capable of maximizing program 'reach'.
21	Panebianco (2016)	**Italy** 80 former clients of a therapeutic treatment agency providing services for substance use issues.	Substance use	Social Capital Theory Social Network Theory Social Support Theory Strength of Weak Ties	Network and outcome data cross-sectional Quantitative The social network analysis examined characteristics of, and relationships among, the people in the respondent's support network.	Partial network *Alter socio-economic status Constraint Density Effective size Network size Occupational heterogeneity Reciprocity*	**Informed design** Findings suggest that upon leaving treatment for substance use issues, individuals are often minimally integrated in the community. Network interventions with a more dynamic role of social workers, counsellors and other health professionals are likely to improve individual capacity to avoid relapse.
22	Peters (2014)	**USA** 30 HIV-infected black MSM who named 95 sex partners and social contacts	HIV partner notification and linkage to care	None.	Network and outcome data cross-sectional Quantitative Contact information was elicited for sex partners from the previous 3 months for index patients with acute HIV infection and the previous 12 months for index patients with HIV infection. Contact information was elicited for social contacts considered to be at high risk for HIV infection. The largest of the resulting networks included 23 black MSM connected by 20 sexual relationships, one social contact, and one molecular phylogenetic link.	Partial network *Clustering*	**Informed design** This degree of clustering and homogeneity suggests that sexual networks among black MSM in North Carolina are highly connected, and that HIV prevention efforts targeting persons (e.g., facilitating access to antiretroviral treatment if HIV-infected or PrEP if HIV-negative) in a central sexual network location might result in substantial decreases in HIV transmission.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
23	Schneider (2013)	**USA** 1187 black MSM generated from 21 seeds and included respondents (n = 204) and other listed network members (n = 983) in Chicago, IL.	HIV prevention	Social Learning Theory Strength of Weak Ties AIDS Risk Reduction Model Theory of Reasoned Action	Network and outcome data cross-sectional Quantitative The Men's Assessment of Social and Risk Networks (SRN Instrument) gathered egocentric network data. A "name generator" was used during face-to-face interviews to elicit from each respondent a set of social network members (social and sexual) who may indirectly affect the respondent's risky behaviors.	Partial network *Assortativity*	**Informed design** Future HIV prevention interventions may benefit from incorporating and potentially altering social networks (e.g. focus on the norms of the network as well as fostering relationships with specific individuals within the network.)
24	Schneider (2012)	**India** 52 truck-drivers at a large transport depot center and from four associated parking lots on the outskirts of Hyderabad in India	HIV prevention	Social Network Theory Strength of Weak Ties	Network and outcome data cross-sectional Mixed-methods A pilot tested social network informed instrument called the Rapid Alter Assessment Instrument was used. The study sought the peer within a truck-driver's network who would likely to be most influential on that driver's HIV risk-taking behavior (e.g. potential change agent). Used focus groups, interviews, and network visualization and analysis. Identified potential peer change agents and their networks.	Partial network *Bridging Closeness Homophily Sociograms Tie strength*	**Informed implementation** The RAAI uses positional analysis in the form of an algorithm to strategically recruit desired network members. Development of social network informed algorithms for specific populations is feasible, and implementation may be automated through digital formats such as computer-assisted participant interviewing.
25	Shakya (2014)	**India** Data from 16,403 individuals in 6,786 households from 75 villages in rural Karnataka, India.	Latrine ownership	Focus Theory of Normative Conduct Strength of Weak Ties Theory of Planned Behavior	Network and outcome data cross-sectional Quantitative A name generator was used in social network data collection to elicit individuals' important connections. Respondents (egos) were asked to name up to 8 social contacts (alters) for each of 12 name generators. For each individual, a continuous measure representing the proportion of her alters was created, including both inbound and outbound ties, that owned a latrine.	Whole network *Modularity Transitivity*	**Informed design, sustainability** The ability to identify the social relevant groups within which norms are held, therefore, is crucial to the science of behavior change and hence to the goal of sustainable health promotion efforts in diverse settings.
26	Thomson (2016)	**USA** 408 women from 3 Ohio Appalachian counties	Smoking cessation	Diffusion of Innovations	Network and outcome data cross-sectional Quantitative Interviewers assessed the specific structural characteristics of a woman's time and advice networks.	Partial network *Density Effective size Frequency of interaction Homophily Modes of interaction Network size Percent of smokers*	**Informed design** These findings could assist with further development and testing of cessation interventions that involve members of the smoker's social network.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
						in the network *Redundancy*	
27	Tobin (2006)	**USA** 659 participants from the Self-Help in Eliminating Life-Threatening Diseases (SHIELD) in Maryland	Drug overdose	None.	Network and outcome data longitudinal Quantitative The study examined the association selfreport of non-fatal overdose between and change in social network characteristics (e.g. total social network, drug using network, support network, and conflict members).	Partial network *Change in density* *Change in network composition* *Density* *Network composition* *Network size*	**Informed design** Results suggest a modification to the traditional design of overdose prevention interventions, which is to expand training in overdose resuscitation techniques to nondrug using social networks.
28	Veinot (2016)	**USA** 194 YMSM who resided in Detroit, MI	HIV testing	Coping Theory Social Influence Theory Social Support Theory Social Systems Theory Theory of Planned Behavior/Theory of Reasoned Action	Network and outcome data cross-sectional Quantitative Web survey asked questions about social network relationships and interactions, HIV testing behavior, sexual and risk behavior, and HIV-related knowledge and attitudes.	Partial network *Density* *Homophily* *Network Range* *Network-Mediated Information Acquisition* *Strong Tie Proportion* *Tie Strength*	**Informed design** Findings suggest the value of multi-level interventions that incorporate network intervention strategies and outcomes in HIV testing interventions among YMSM.
29	Wagner (2016)	**USA** 125 African American HIV-positive men in Los Angeles, CA.	HIV Stigma	HIV Stigma Minority Stress Model Social Support Theory	Network and outcome data longitudinal Quantitative Participants were administered surveys and an egocentric social network assessment that included several measures of perceived HIV stigma among alters.	Partial network *Alter HIV stigma* *Density* *Percentage of isolates*	**Informed design** Findings support the value of interventions such as those based on the popular opinion leader, and peer change agent models. Strategies to promote sexual health among persons living with HIV/AIDS could target the support provided by the most popular members of their networks, or work with persons living with HIV/AIDS to examine who they interact with and consider changes that would elevate well-connected, nonstigmatizing network members to greater prominence within the network.
30	Wong (2011)	**USA** 252 people with serious mental illness who resided in independent housing in large urban county	Serious Mental Illness (SMI)	Social Capital Theory Social Exchange Theory Social Support Theory	Network data cross-sectional Quantitative Research interviewers asked participants to name people whom they considered important in their lives, according to different types of relationship (e.g. family, friends). Transactional (i.e., support exchanges) characteristics of social networks, especially the reciprocation of exchanges between	Partial network *Density* *Intensity of contact* *Negative reciprocity* *Network composition* *Network size* *Positive reciprocity*	**Informed design** Reciprocity may have programmatic implications for interventions like supported socialization programs that assist individuals with psychiatric disabilities in expanding their social networks.

#	Author(s) / Year	Population/Sample	Health Topic	Theories	Methods / Study Design	Network Type(s) and Measures	Network Intervention Implications (Design, Dissemination, Implementation, and/or Sustainability)
					residents and their network members, were analyzed		
31	Zhang (2015)	**Online** Data is from 233 users, and 228 threads (228 posts and 1,672 comments) were randomly selected as a sample for analysis (from QuitStop forum).	Smoking cessation	Social Support Theory Transtheoretical Model / Stages of Change	Network and outcome data cross-sectional Mixed methods The content of user discussions as well as the patterns of user interactions were analyzed. Qualitative analysis was used to analyze the types of social support on QuitStop forum and to extract and define user interaction patterns of social support exchange.	Online network *Blockmodel* *Network exposure*	**Informed design** Studies of social support and support exchange behavior in online health communities could help us better understand user motivations, actions and smoking cessation outcomes in online intervention programs.
32	Zhao (2014)	**Online** 48,779 threaded discussions with more than 468,000 posts from more than 27,000 users in the American Cancer Society Cancer Survivors Network®	Cancer	None.	Network data longitudinal Quantitative Identified leaders in an online health community for cancer survivors and informal caregivers. Extracted information on leadership of a user: contribution, network, linguistic features. Incorporated the structure of the network among users into the extraction of various types of user features, including neighborhood-based and cluster-based features.	Online network *Betweenness centrality* *In-degree* *Out-degree* *PageRank centrality*	**Informed design** Research could have important implications for online health community (OHC) users and administrators. This work allows an OHC to encourage users' participation by awarding prestigious status to leaders who have been more accurately identified.

[1] Articles in the review that proposed application of SNA to inform behavioral interventions.

[2] Count includes the 32 articles in this table as well as the Lorway et al (2010) entry in Table 3, which was categorized as both applied and proposed.