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Social networks and future direction for obesity research: A scoping review

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Abstract

Despite significant efforts to decrease obesity rates, the prevalence of obesity continues to increase in the United States. Obesity-risk behaviors—physical inactivity, unhealthy eating, and sleep deprivation—are intertwined during daily life and are difficult to improve in the current social environment. Studies show that social networks—the thick webs of social relations and interactions—influence various health outcomes, such as HIV risk behaviors, alcohol consumption, smoking, depression, and cardiovascular mortality; however, there is limited information on the influences of social networks on obesity and obesity-risk behaviors. Given the complexities of the bio-behavioral pathology of obesity, and the lack of clear evidence of effectiveness and sustainability of existing interventions that are usually focused on an individual approach, targeting change in an individual's health behaviors or attitude may not take socio-contextual factors into account; there is a pressing need for a new perspective on this problem. In this review we evaluate the literature on social networks as a potential approach for obesity prevention and treatment: how social networks affect various health outcomes and present two major social network data analyses (i.e. egocentric and sociometric analysis); and discuss implications and future direction for obesity research using social networks.

Keywords

social networks; obesity; scoping review

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Introduction

Overweight or obesity—one of the most preventable causes of morbidity and mortality in the U.S. (United States)¹—contributes nearly 17% to total U.S. medical costs.² By 2030, the prevalence of overweight in the U.S. population will increase to 86%, and 51% of these individuals will be considered obese.³ By 2050 one in three U.S. adults could have type 2 diabetes (T2D).¹ Similarly, significant number of people could develop obesity related condition such as nonalcoholic fatty liver disease, stroke and other cardiovascular diseases (CVDs).^{4,5} As a result, obesity-related morbidity and mortality is expected to increase in the future.^{1,6} Despite significant efforts to reduce obesity, modifiable risk factors such as the rates of physical inactivity, high fat and high calorie food consumption, and sleep deprivation in the U.S. continue to increase.

Interventions to reduce and prevent obesity have not been successful. Obesity interventions provided in clinical rather than in community-based settings often show very low participation rates. Even in community-based physical activity interventions, the dropout rate is up to 50%.^{7,8} In addition, most weight loss interventions that include physical activity or dietary components show short-term effects, but the majority of participants regain weight within five years of the intervention.⁹ Given the complexities of the bio-behavioral pathology of obesity, accumulating data show that simultaneously changing multiple health behaviors is crucial to preventing and effectively tackling obesity,^{1,2,10,11} but there is a lack of clarity regarding which combination of strategies is the most effective and sustainable. These obesity-risk behaviors—physical inactivity, unhealthy eating, poor sleep behavior (e.g., voluntary or involuntary sleep deprivation)—are intertwined with each other during daily life and are difficult to improve without considering the contextual factors of the social environment.^{12,13}

There are many challenges to adopting healthy behaviors, especially in the current social environment (e.g., increased portion sizes, proliferation of fast food restaurants, reduced opportunities for physical activity) (Table 1).¹⁴ Recent findings suggest that social networks, the webs of social relations and interactions,¹⁵ may also contribute to obesity risk behaviors. Social networks have a powerful influence on many health behaviors with negative influences on HIV risk behaviors, alcohol consumption, and smoking through social influences and person-to-person contact.^{16–20} In contrast, social networks positively influence depression and CVD through social support.^{21–23} Obesity is a risk factor for depression or CVD,²³ which may be also influenced positively or negatively by social networks;^{21,22} however, knowledge of the relationship between obesity-risk behaviors and social networks is very limited.

The purpose of this review is to evaluate the literature on social networks in order to determine their relevance as a potential approach for modifying behavioral risk factors for overweight and obesity. We first discuss concepts often used in social network research and how social networks affect health outcomes and introduce two major methods of social network analysis (i.e., egocentric and sociometric analysis). Second, we summarize research that supports the positive and negative influences of social networks on health outcomes. Third, we describe research related to social determinants of obesity and propose a

conceptual model of social networks and their influence on obesity. Last, we discuss future directions for obesity research using social networks.

Methods

We conducted a scoping review of the scientific literature in which we mapped or summarized a wide range of literature to convey the breadth and depth of the field and identify gaps in existing literature and innovative approaches.²⁴ Researchers use this method to clarify a complex concept and refine subsequent research inquiries.^{25,26} Scoping reviews are particularly relevant to emerging areas of research or areas where a paucity of randomized controlled trials makes it difficult for researchers to undertake systematic reviews.²⁶ Unlike systematic reviews, scoping reviews identify all relevant literature regardless of the study design and the reviewers do not typically assess the quality of included studies.^{26–28}

Our study is guided by Arksey and O' Malley's methodological framework: identifying the research questions, identifying relevant studies, selecting studies, charting the data, collating, summarizing, and reporting the results.²⁸

Identifying the research questions

We identified the following research questions: (1) what is known about social networks in health research? 'Social networks' is an umbrella term that could include a type of social relationship, social tie, social norm, and social influence. Thus, we determined how these terms were defined and used in health care research. (2) What are the positive and negative influences of social networks on health and health behaviors? (3) Are obesity risk behaviors social behaviors that may be influenced by social networks? We also identified research gaps, formulated a conceptual framework for obesity research, and identified implication for future research.

Identifying relevant studies and studies selection

A literature search was conducted in four reference databases: PubMed, CINAHL, PsychINFO and Scopus, with Boolean operators used as parameters. The search was limited to citations from 1970 to 2014 because several classic articles on the influences of social environments on health were published during the mid-1970s. We used the following terms: social networks, social network analysis, social influence, social tie, social norm, social support, health, health behaviors, risk behaviors and obesity. A comprehensive search was performed to identify articles on social networks and obesity. However, for articles on social networks and other health outcomes, we used purposive sampling strategies to provide an overview on social network concepts, research methodology, and positive or negative influence of social networks. The final search approach included hand searching reference lists to identify additional articles. The process of identifying relevant studies for a scoping review is not linear, but iterative.²⁸ Where necessary, we repeated steps to ensure that the literature was covered in a comprehensive way for each research question. There were large variations in the number of references generated by each of four databases: PubMed (n = 2,606), CINAHL (n = 9,636), PsychINFO (n = 2,990), and Scopus (n = 7,567). Following

the removal of duplicates and screening from abstract reviews, we reviewed the full text of the manuscripts. The final process resulted in the identification of 74 articles that were appropriate for the review (Figure 1).

Charting, collating, and summarizing

Data from each publication included the authors, date of publication, study population, aims of the studies, outcome measures and main findings. We organized the literature thematically, according to social network concepts, research methodology, negative and positive influences of social networks on various health conditions or health behaviors and the study population (e.g., children vs. adults). An overall description of the material was compiled. We compared the different studies to identify gaps in research on social networks and obesity and reported the results as a narrative summation that emerged from the analysis of the literature, focusing on research questions.

Results and Discussion

Concepts in social network research

The term “social networks” refers to a set of individuals and the ties among them;²⁹ health and behavioral scientist have a long-standing recognition of the role of social networks on health and health behaviors in various conditions.^{20,30–34} Structural and functional characteristics underlie the relationship between social networks and health.³⁵

Structural characteristics of social networks focus on the members of the network, including the number of network members, stability (turnover rate of members) and density (interconnectedness among network members). The structure of social networks is largely responsible for determining an individual’s behavior and attitudes by shaping the flow of resources that determine access to opportunities and constraints on behavior.¹⁶ For example, a lack of social ties (i.e., few supportive social network members) predict mortality of adults experiencing strokes and cancer.^{36–39}

Functional characteristics include the processes of social relations that affect health outcomes. Social networks affect health by providing tangible support such as money or housing, and intangible support such as emotional, informational support, sharing social influences (norms), social engagement, person-to-person contact such as HIV or influenza virus transmission and increasing access to resources.¹⁶

Social support—one of the most extensively studied functional characteristics of social network research—is divided into subtypes categorized as emotional, instrumental, appraisal, and informational.⁴⁰ Emotional support is related to the amount of loving and caring, sympathy and understanding from others.⁴⁰ Instrumental support refers to help, aid or assistance with tangible needs such as getting groceries, getting to appointments, cooking, cleaning or paying bills.⁴⁰ Appraisal support includes decision-making, giving appropriate feedback, or help deciding which course of action to take.⁴⁰ Informational support includes the provision of advice or information in the service of particular needs.⁴⁰

The relationships between the functional and structural roles of social networks may not be mutually exclusive.⁴¹ For example, someone with many strong social ties (great number of close relationships) may receive more emotional support than others with few strong social ties. In strongly connected networks (i.e., networks with high density, for example, “my close friends are friends of five others”), one may not receive informational support because people who communicate with each other frequently are likely to be exposed to the same information. People in strongly connected networks are likely to share a similar level of social capital including novel information. Therefore, there may be redundant information circulating within the network.⁴²

In addition to social support, *social influences*—the ways members of a social network obtain normative guidance about health behaviors such as practicing safe sex, cigarette smoking, or drinking by comparing their attitudes with those of a reference group of similar others,¹⁶—contribute to behaviors such as HIV, sexually transmitted disease (STD) risk behaviors, smoking, and alcohol consumption.^{17,18,20} For example, shared norms around health behaviors are powerful sources of social influence affecting the health of adolescents.^{18,43}

Social networks may also influence health by promoting *social engagement* and social integration that produce positive psychological states for sociability, including a sense of purpose, belonging, security, and a consistent sense of identity.⁴⁴ Getting together with network members, attending social functions, participating in social roles, and church attendance are all examples of social engagement. *Person-to-person contact* is another behavioral pathway by which networks influence health, especially in infectious disease transmission (e.g. flu virus, STDs) and secondhand cigarette smoking. *Social capital*—the resources available in one’s network—provides access to job opportunities⁴⁵ and *access to health information* for better or more appropriate health care.

Methods of social network analysis

Social network analysis refers to a study of egocentric networks with an individual at the center—from the perspective of the individual – or sociometric networks with entire networks of networks at the level of communities (i.e., collection of connected individuals). There are overlaps among egocentric network analysis, sociometric network analysis, and mainstream social science research in terms of areas of study. For example, mainstream social science may evaluate the social influences and the effect of social support on health, which overlaps with evaluation of egocentric social networks. Both egocentric network analysis and mainstream social science research focus on personal or the individual’s perspectives whereas sociometric network analysis focuses on the totality of individuals in a determined population and all the links between them. In egocentric network analysis, researchers collect data in the same way as mainstream social scientists do but also describe the interactions between network members and an index person and network characteristics (Figure 2).

Egocentric network analysis—Egocentric networks, also known as personal networks or ego networks, consist of the “ego” (index person) at the center, together with alters

(network members) who are directly connected to the ego.⁴⁶ Researchers use egocentric data to evaluate the extent to which people who engage in certain behaviors are more likely to have close personal network associates who also engage in those behaviors.⁴² In other words, this type of analysis captures social influence, social support, and access to resources by measuring the extent to which one's network engages in a behavior.⁴² From the perspective of egocentric network analysis, relevant questions concern the phenomena affecting individual entities across different networks.⁴⁶

Egocentric data are collected with questions to an index person: "Who are your five best friends?", "Who do you talk to about important matters?" or "Whom do you talk to most frequent about a topic?"⁴⁷ Additional information is also collected on the relationships between the respondent (index person) and the persons nominated (network members or alters), and all respondents' attributes including demographic, relationships, and behaviors. Egocentric data analysis includes the following: network size (How many contacts does ego have?), composition (Are ego's alters all alike?—homogeneity), (Does ego interact with others like himself/herself?—homophily), and structure (Does ego have ties with non-redundant alters?). After collecting both relationship data and attribute data such as socioeconomic status, beliefs, health behaviors, health knowledge from index persons, researchers analyze the data regarding how an individual's decisions on health behaviors are influenced by the groups of people connected to one another. For example, network members may exert by lending or borrowing drug injecting equipment from each other or by exchanging information on injecting practices, the major risk factors for transmission of HIV and Hepatitis C.^{48,49} Similarly, an individual who has a greater number of network members to do certain activities together such as dancing or shopping may have lower obesity-risk behaviors than an individual who has a greater number of network members who drink alcohol with high-calorie, high-fat snack consumption.

There is often an assumption that social networks influence the index person because of the index person's perceptions about network members' engagement in the behaviors;⁴² however, the respondents (index persons) may not be accurate regarding their network members' actual behaviors or relationships. Despite this shortcoming, many studies consistently show that an individual's perception of his/her network members' behaviors may play a more important role in accepting health care information/advice or operating self-care behaviors than the network member's actual behavior itself.⁵⁰ For example, Valente and associates found that women in a voluntary organization in Cameroon misjudge their friends' contraceptive use.⁵¹ In this study, a perceived friend's contraceptive use was associated with one's own use, regardless of the accuracy of those perceptions.⁵¹ The authors highlighted the importance of perceived peer influence and explained that to some extent people may justify their behaviors by considering whether their behaviors would be supported by peers.⁵¹

Sociometric network analysis—Sociometric networks, also known as whole or complete networks, consist of entire networks of networks at the level of communities or workplaces.⁴⁶ Sociometric network analysis is a new area of social network research and ideal for assessing the collective dimension of social ties—"network of networks" or "web of relationships."⁴² It provides information on all relationships within a bounded social

network and yields rich data in direct and indirect connectedness in the entire social networks.⁵² A relevant research question using sociometric network analysis addresses different patterns of interaction within defined networks; for example, who are the key players in a group? How do ideas diffuse through a group? Sociometric data are collected by interviewing all people in the community of interest and asking about their contacts/relationships within the community. Because a sociometric sample requires interviewing all people, including their contacts within the community of interest²⁹ and the challenge of defining community boundaries, sociometric analysis has seldom been employed in epidemiologic investigations.^{53,54} Sociometric network analysis, however, is particularly useful for studying a change in network structure over time (i.e., network's centrality: circle type network [less centralized]– chain type network – Y shape network – wheel shape network [more centralized]), concentration of power (e.g., powerful position, or key player), and flow of information or resources. For example, an individual's position in a network determines in part the opportunities and constraints to health service access or adoption of health behaviors.

Positive and negative effects of social networks on health outcomes

Social network analysis has increased in health research over the last decade and has primarily focused on drug and alcohol use, smoking, and other infectious disease risk behaviors.^{55–59} A systematic review of adolescents' smoking behaviors shows that initiation of smoking was influenced by peer group structure; that is, if non-smoking adolescents belonged to a "smoking clique" compared to a "non-smoking clique," the adolescents were more likely to become smokers. Similar tendencies were also observed for quitting behaviors.¹⁸ The presence of drinking buddies in an individual's networks is likely to increase the individual's alcohol consumption.^{60,61} On the other hand, having network members who abstain from alcohol use is associated with decrease alcohol consumption.⁶² Two possible mechanisms of social network effects on individuals' smoking/drinking behaviors include peer selection and peer influences. Peer selection (homophily) occurs when individuals choose friends whose behaviors or attitudes are similar to their own.⁶³ Peer influence occurs when the individuals lead others to adopt or quit their behaviors. Researchers have attempted to tease out whether peer selection or peer influence plays a more important role in individuals' smoking/drinking behaviors by using social network analysis; however, the results of the studies are mixed, in part due to the variation of sample characteristics (e.g., different age, gender, and race groups), measurement, and study design.

Social network structure (e.g., size, density), social norms, and social engagement influence a number of HIV/STD risk behaviors.^{20,30–34} Having more network members who use crack increases the risk for engaging in sex exchange. Peer norms for syringe sharing are also associated with receptive needle sharing among young adult intravenous drug users (IDUs).³⁰ Several other studies also found an association between norms and unprotected sex⁶⁴ and exchanging sex for money and drugs within the social networks.⁶⁵

Numerous studies have shown the positive role that social networks, specifically social support and social integration, have in morbidity and mortality in cardiovascular diseases (CVD), including stroke and coronary artery disease.^{38,39,66} Adults with low levels of social

support or social integration had higher CVD mortality compared to those with high support or social integration from their network members, even after accounting for other factors such as severity of disease. Similarly, socially isolated women were more adversely affected by breast cancer than women who were more socially integrated. Social networks influence mental health outcomes positively by increasing social support and social integration or negatively by providing a significant source of stress within certain contexts (i.e., role strain)^{16,54} For example, studies found that smaller social network size and lack of close relationships were linked to depressive symptoms.^{54,67} Although establishing a causal relationship in social networks still needs more research, there are plausible explanations about the association. That is, social ties serve as a provision of social support and social integration may play a beneficial role in psychological well-being by increasing motivation for self-care and modulating the neuroendocrine response to stress.⁶⁸ Social networks may also have negative effects on mental health and may vary by socioeconomic position and gender.⁵⁴ For women with lower socioeconomic position, as compared to women with higher socioeconomic positions, participating in social relationships may be more harmful than helpful because women with lower socioeconomic positions often face greater difficulty in responding to the needs of network members and engagement in social networks entails psychological cost associated with a sense of obligation.⁵⁴

Given the positive and negative influences of social networks on health, researchers conducted intervention studies targeting change in social networks. While more research is needed to understand both potential pitfalls and advantages of social networks, there is some evidence demonstrating a greater improvement of risk behaviors among network members when the intervention targets the social network (e.g., peer educators intervene with their network members)^{19,20} Table 2 presents some examples of the effects of social networks on various health outcomes and intervention studies using social networks.

Obesity in the context of social networks

Obesity-risk behaviors as social behaviors—Physical inactivity and unhealthy eating are well-known risk factors for obesity; a growing body of research also suggests that there is link between sleep deprivation and obesity.^{69–76} More importantly, low levels of physical activity, unhealthy eating, and sleep deprivation are closely interrelated and contribute to obesity.^{70–72} For example, sedentary behaviors such as TV viewing, computer and internet use are associated with greater consumption of sweetened beverages and over-consumption of food.^{73,74} Chronic partial sleep deprivation due to voluntary (e.g., social activities, TV viewing) or involuntary (e.g., work, caregiving, sleep disorders) reasons contributes directly to weight gain by decreasing leptin (satiety hormone) and increasing ghrelin (hunger hormone).^{70–72,75,76} Despite many efforts to improve behavioral risk factors for obesity, the rate of physical inactivity, high fat and calorie consumption, and sleep deprivation continue to increase in the U.S.,^{77–79} and certain ethnic minorities such as African Americans have higher rates of all the obesity-risk behaviors compared to Non-Hispanic Whites.^{80–84}

Physical activity and eating are “social behaviors” that people often share and are influenced by social norms and social support.⁸⁵ Adolescents’ physical activity levels have been

positively correlated with perceived social support from friends.⁸⁶ In a study examining whether children's friendship networks in afterschool programs influences their physical activity, the study revealed that children as young as 5 to 12 years of age made adjustments to their activity levels of 10% or more to emulate the activity level of their peers. Adolescent girls were more physically active when they reported that their close friends engaged in high levels of physical activity.⁸⁷ Although there are preliminary findings on the relationship between physical activity and social networks among adolescents, less research has focused on the relationship between physical activity and social networks among adults.

The influences of social networks on healthy eating have also been described. Studies show that adolescents' consumption of snack foods⁸⁸ and foods high in saturated fat⁸⁹ is influenced by their social network members.⁹⁰ In the Framingham Heart Study with 3,418 adults, alcohol consumption and snacking behaviors were shared by socially connected individuals across all relationships including friends, spouses and sibling peers, which supports evidence of a social influence process on eating behaviors.⁹¹

Although less is known about social network influences on sleep, recent evidence shows a growing area of interest in social relationships and sleep, particularly in the context of family socialization.^{92,93} Troubled sleep is associated with less family support and more family strain among adult household members.⁹² Furthermore, the risk of troubled sleep associated with family strain increased as family contact became more frequent (i.e., by asking "how often are you in contact with any members of your family?"), indicating that the role of social contact in promoting sleep health largely depends on the content and quality of the social exchange.⁹² Shared values or attitudes toward sleep and sleep hygiene practices and other social activities such as physical activity (e.g., amount, timing) and diet (eating near bed time, consumption of alcohol and caffeine) within social networks may contribute to sleep loss.^{94,95}

Social networks and obesity—Researchers have recently begun to link social networks to obesity. Studies of adolescents' friendships demonstrate that the weight status of close friends and other non-biological network members influence an individual's weight status.^{96,97} In other words, adolescents' friendship selection was driven by peers' weight status. Specifically, adolescents who were not overweight preferred to initiate friendships with peers whose weight status was the same as their own (peer selection and homophily).⁹⁷

A 32-year longitudinal study of the Framingham cohorts showed that a person's chances of becoming obese increase by 57% if he/she had friends who became obese in a given interval.⁹⁸ Investigators demonstrated the influence of social networks on health behaviors and suggest that social distance (i.e., frequency and intensity of interactions between two parties) plays a stronger role than geographical distance in the spread of behaviors or norms associated with obesity.⁹⁸

Similarly, Leahey et al. conducted a study to examine whether shared social norms that valued weight loss among network members influence intention to lose weight among young adult network members.⁹⁹ Compared to the young adults with fewer social norms who valued weight loss, young adults with greater social norms who valued weight loss

reported more social contacts (romantic partners and best friends) who have similar values on weight loss and thus greater intention to lose weight.⁹⁹

Taken together, there are several plausible mechanisms explaining the link between social networks and obesity: individuals' similarity in weight status may be explained by individuals forming friendships with peers similar to them in weight status (homophily), by their shared school contexts and environment (confounding effect), by influences of individuals' weight norms and its indirect effect on individuals' weight management, or by having similar engagement in obesity-risk behaviors among individuals, and in turn contributing to their actual body mass index (BMI).^{96,100–103}

Example of social network analysis in obesity intervention—Although group-based interventions promoting physical activity and healthy eating have been reported over the last decade, few studies were designed or analyzed from social network perspectives. Gesell et al. recently conducted a community-based, culturally tailored obesity intervention with 79 Latino parent-preschool child dyads to examine whether new social networks evolve between families participating in the obesity prevention trial over the course of study.¹⁰⁴ In her study, parents not only selectively formed new friendships with parents whose children have similar body types, but also showed their inability to recognize their own child's overweight status or their high tolerance toward their child's overweight status.¹⁰⁴ Therefore, parental misperceptions or high tolerance about their children's overweight status may influence how parents take action to ameliorate their children's weight problem. More importantly, the study suggests that in the delivery of group-based behavioral interventions, the process of social network formation and group dynamics should be taken into account to evaluate the effect of an intervention (e.g., effect size) which may overestimate or underestimate the effect of the intervention based on the group dynamic.¹⁰⁴

Proposed conceptual framework and other considerations

Based on the research on social networks and health, an overall proposed heuristic model of linking social networks to obesity is presented in Figure 3 by modifying social network theory.¹⁶ We used an established social network theory¹⁶ and incorporated research on social networks and health to increase the specificity of the theory to obesity-risk behaviors and outcomes. Tentative relationships have been proposed for future evaluation.

Structural and functional characteristics of social networks influence health via several other pathways.¹⁶ For example, social network structure and function may directly contribute to obesity-risk behaviors by shared social activities, social influences, and social support or indirectly contribute to obesity-risk behaviors or obesity in the relationship with environmental, sociodemographic, psychosocial and clinical factors.

Environmental factors and individual-level determinants such as sociodemographic (sex, race/ethnicity, income, education, marital status, employment status), psychosocial factors (attitudes/stigma toward obesity, perception about weight status, self-efficacy), and clinical factors (chronic illness comorbidities, genetic factors, smoking, drinking behaviors) condition the extent, shape, and nature of social networks that directly contribute to obesity-risk behaviors or obesity through feedback mechanisms.^{105,106} The importance of

environmental factors on the obesity epidemic in the U.S. has been well documented^{107–109} Lack of access to healthy food stores and recreational facilities and unsafe neighborhoods are not only associated with unhealthy eating and physical inactivity^{107–109} but also with other negative outcomes in mental health, risk behaviors (drug use, violence) and poor sleep and in turn obesity. Social networks are embedded in and shared within and across different environments and communities. Environmental factors are likely to interact with sociodemographic factors because sociodemographic factors such as race/ethnicity and socioeconomic positions are determinants of neighborhood of residence.^{100,103} In other words, individuals' sociodemographic profiles may be the basis for social affiliation—social networks.¹⁰³ Therefore, adjusting for the effect of shared environments on obesity among network members and examining environmental factors as confounders of obesity are important to understand the specific influence or mechanisms of social networks on obesity-risk behaviors and to develop effective behavioral interventions of social networks.

Psychosocial factors are well-known factors that may contribute directly to an individual's obesity-risk behaviors or obesity. For example, significant, positive relationships between self-efficacy and exercise and eating behavior across different age and racial/ethnic groups have been documented.^{110,111} Attitude toward obesity and social stigma related to obesity, have been shown to affect individuals' eating and physical activity behaviors as well as psychological well-being.¹¹²

Clinical factors such as chronic illness comorbidities, genetic factors also influence obesity-risk behaviors or obesity by interacting with environmental and the individual-level determinants. People with multiple chronic comorbidities frequently report experiencing barriers to implementing healthy behaviors due to the simultaneous demands of competing comorbidities such as arthritis, asthma, congestive heart failure, and depression.¹¹³ A growing body of literature has also demonstrated that genetics not only influence BMI and fat mass, but also influences obesity-risk behaviors such as an individual's food preference/intake, propensity to physical activities. Individuals with obesity-predisposing genes may be particularly responsive to the influences of an "obesogenic environment."¹⁴

Discussion and implications for future research

The prevalence of obesity is overwhelmingly high in the U.S. and continues to increase.³ Historically, obesity programs have relied on an individual level approach focusing on changing individual behaviors and attitudes. In the last two decades, there have been great efforts in community-based obesity interventions working collaboratively with various stakeholders: communities, neighborhoods, businesses, health care institutions, and public health departments. What has been missing in current efforts to reduce obesity, however, is the importance of understanding obesity in the social context—the effect of social networks.

Future research efforts should include testing the components of the aforementioned conceptual model because there are likely to be complex interactions among factors. In addition, the strength of empirical evidence on the influence of specific factors in the model needs to be evaluated in different settings and populations. Recently, more sophisticated analysis procedures allow researchers to visualize social network structure, disease epidemics and social capital (i.e., related health care resources) within and across social

networks. For example, how does a position in a network (e.g., isolate, member, liaison) determine the opportunities and constraints to health care resources? Graph or map properties that characterize network structure, position, dyadic relationships and overall distribution of social ties help us understand complex social relations with other variables. Detailed discussion about software and statistical packages of social network analysis is beyond the scope of this paper. A variety of software for social network analysis are now available (e.g., UCINET, Pajek, R, ERGM, SIENA, Stata, SAS) to map and measure the relationship among components in a complicated social network model. With single network observations it is not possible to disentangle the process of social selection (homophily) or social influence; however, through subsequent longitudinal research we can examine not only how a network and related health outcome evolve over time but also distinguish the process between social selection and social influence for certain health conditions and health behaviors. Longitudinal and experimental studies that would help establish a causal relationship are needed to determine which structure or function of the social networks predict obesity risk-behaviors. This effort will also contribute to develop social network intervention targeting obesity by better understanding of facilitators/barriers to maintain health behaviors.

The research reviewed here provides current knowledge on the effect of social networks on various health outcomes and why obesity-risk behaviors should also be understood in the context of social networks. Despite these promising links to obesity and obesity-risk behaviors, there are several issues that will require increased attention in future research. One issue is measurement. Social network research regarding obesity is different from social network research for other health issues such as infectious disease (e.g., via person-to-person contact) in terms of measuring the process of social networks and their effect on obesity-risk behaviors. Transmission of behaviors or psychosocial states may not be measured directly and ruling out other reasons for shared behaviors or attitudes among socially connected people may be necessary.¹¹⁴ There may even be omitted variables that have some confounding effects if pairs of friends and neighbors who participate are more similar to each other on unmeasured attributes.^{100,114} For example, previous attempts to describe shared behaviors and norms between network members and the relationship with obesity may have been limited in the sense of determining a specific causal relationship, due in part to environmental and sociodemographic factors embedded in social networks. Along the same line, future research will need to examine mediating, and moderating effects in a relationship of social networks and obesity guided by theory or previous research. This process is crucial to develop and evaluate interventions—how and for whom an intervention affects outcomes and by what mechanism.

Structural characteristics of social networks such as network size, stability (turnover rate of members), and density may be relatively easier to capture by quantitative methods (either egocentric or sociometric data) than the context and functional characteristics of social networks. To develop an effective obesity intervention, a comprehensive understanding of how social norm/social influences develop and circulate in social networks is necessary. Therefore, incorporating qualitative methods into social network analysis would enhance our understanding of social contexts in obesity-risk behaviors and help explore potential confounders that have not been determined in previous obesity research. For example, by

integrating ethnographic methods in child obesity research, Kaufman and colleagues demonstrated that the meaning families generate about food, well-being, obesity, and parental identity influence health behaviors that can ultimately affect weight and overall health.¹¹⁵

Another important issue in obesity research using social networks is the need to carefully consider both negative and positive effects of social networks on obesity. Obesity-risk behaviors are likely to be affected both negatively and positively by social networks. Strengthening social ties that provide social support but do not spread risk behaviors, and reducing ties that provide negative influences on healthy eating or sleep may improve obesity-risk behaviors. As with previous social network research in other health problems, identifying opinion leaders or key players whose function is legitimizing health behavior change or identifying a positive role model in the networks would be helpful in obesity interventions, as the opinion leader or positive role model could recruit (nominate) network members and implement the interventions.⁴² Similarly, peer education may be a useful strategy targeting both positive and negative effects of social networks, by increasing shared physical activity or decreasing unhealthy eating or other risk behaviors. Peer educators or key players can spread information and resources through social networks. Taken together—not only investigating social network determinants of obesity but also considering the positive and negative function of social networks—will guide effective obesity interventions and provide an undistorted estimate of the relationships (e.g., reliable effect size of interventions).

Last, it is also important to identify target populations who would benefit most (or least) from such interventions and determine the key person in spreading information or behaviors in social networks. For example, adolescents whose peer group positions are isolates (i.e. participants in friendship who do not associate their identity with any particular group) may be considered as a high-risk target population who are more likely to use tobacco than those who belong to peer group.^{116,117} Thus, intervention programs that assist individuals to join and function in cliques may be effective as preventive measures.¹¹⁸ Along the same line of investigation, a low score in a social network screening does not necessarily reflect a perceived need for greater support. In other words, someone with small social networks may not feel that additional social support is needed. Identifying individual characteristics of need for support interventions will improve the receptivity to the support intervention when it is provided.^{54,119} Future efforts should include the following: understanding mechanisms of social network function on obesity risk behaviors, addressing fundamental questions to understand contextual factors of social networks and obesity across diverse race/ethnicity, and further development of innovative methodology and technology to facilitate and improve the utility of social networks on obesity.

Conclusions

In summary, the challenge of future work in social network research is to develop effective obesity interventions by understanding obesity as a complex social problem. We proposed a social network model, specified to obesity-risk behaviors and outcomes for further development and evaluation. More research efforts are needed to understand the influences

that social networks' structure and function have on health behaviors among individuals of different age, gender, and race/ethnicity groups. How do different age, gender and race/ethnicity groups differ by the networks' group process? What are positive or negative influences of social networks in diffusing and creating norms that favor obesity-risk behaviors? Furthermore, more research is needed regarding how the structure and function of networks change over time and their impact on an individuals' health using different study designs and comprehensive methodology (e.g., online and offline). Social network analysis allows us to see a larger population by showing whole groups of individuals and their connectedness and has various avenues to provide cost effective interventions in the future. Ultimately such interventions have high potential to contribute to the reduction of obesity and obesity- related morbidity and mortality, and to reduce the cost of health care.

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Highlights

- Social networks have positive and negative influences on various health outcomes.
- Obesity risk behaviors are “social behaviors” influenced by social networks.
- Social network research has a potential to reduce the burden of obesity.

Figure 1.
Study identification strategy

Figure 2.

Data and perspectives of social network analysis

Adapted from Rich DeJordy and Dan Halgin, 2008 Academy of Management Professional Development Workshop presentation delivered in Anaheim, California and posted online here: <http://www.analytictech.com/e-net/pdwhandout.pdf>.

Figure 3.
Conceptual model linking social networks to obesity

Table 1**Challenges to adopting healthy behaviors in the current social environment**

- Increased portion sizes, “super-sizing” of commercially available foods
- Access to energy-dense foods in schools and work (e.g., high-energy-dense snacks and sugary drinks sold in vending machines)
- Proliferation of fast-food restaurants
- Difficulties to obtain nutritious food in low income communities due to lack of supermarkets and limited access to healthy, fresh food
- Advertising of less healthy foods
- Two or more televisions in most households
- Use of labor-saving devices that reduce physical activity (e.g., electronic cleaning devices)
- Lack of safe and appealing place to play or be active in many communities
- Lack of protected bike lanes and pedestrian-friendly streets
- Lack of sleep due to busy lifestyles, or night-time use of electronic entertainment (e.g., TV, computers, video games, cell phones, movies)

Table 2

Examples of social network studies

Authors (years)	Sample	Design (data collection method)	Aims	Major findings [Components of social network characteristics]
Berkman et al. (1979) ³⁹	6,928 individuals	Prospective, observational study (survey)	To examine the impact of social ties and networks on all causes of mortality in a larger sample of a general population.	<ul style="list-style-type: none"> People who lacked social ties were more likely to die in the follow-up period than those with more extensive contacts (Age- and sex specific mortality rates, age-adjusted relative risks and the chi square values for the age-adjusted differences in mortality were all highly significant ($p < 0.001$)). <p>[Social engagement; social support]</p>
Berkman et al. (1992) ⁶⁶	194 elderly men and women over 65 years of age who were hospitalized for acute myocardial infarction	Prospective, observational study (survey)	To compare the survival of elderly patients hospitalized for acute myocardial infarction who have emotional support with that of patients who lack such support, while controlling for severity of disease, comorbidity, and functional status.	<ul style="list-style-type: none"> Lack of emotional support was significantly associated with 6-month mortality after controlling for severity of myocardial infarction, comorbidity, risk factors such as smoking and hypertension, and socio-demographic factors (OR, 2.9; 95% CI, 1.2–6.9). <p>[Social support]</p>
Beal et al. (2001) ⁸⁸	208 students in the seventh-grade	Cross-sectional study (survey)	To determine whether parent social influences are associated with health-risk behaviors more than peer social influences among young minority adolescents.	<ul style="list-style-type: none"> Parent influences were associated with differences in alcohol use ($p < 0.01$). Peer influences were associated with differences in all measured health-risk behaviors: tobacco ($p < 0.05$) and alcohol use ($p < 0.01$), sexual activity ($p < 0.05$), and marijuana use ($p < 0.05$). <p>[Social influence; homophily]</p>
Bullers et al. (2001) ⁶⁰	1,933 adults in Erie County, New York	Prospective, observational study (survey)	To compare the effect of the social selection and influence on drinking patterns among adults.	<ul style="list-style-type: none"> Both social selection ($p < 0.01$) and social influence ($p < 0.01$) affect the association between individual and network drinking patterns among adults. Social selection effects are substantially stronger than social influence effects. <p>[Social influence; homophily]</p>
Bailey et al. (2007) ³⁰	3,285 persons aged 15–30 years	Cross-sectional study and reports from results of the intervention (audio computer-assisted self-interviews at baseline. Some participants enrolled in an HIV/HCV (hepatitis C) prevention intervention trial	To examine risk factors for receptive syringe sharing (RSS) during illicit drug injection in 5 US cities.	<ul style="list-style-type: none"> Perceived risks ($p < 0.001$) peer influences ($p < 0.001$), and type of injection partner ($p < 0.01$) were robust predictors of RSS. Perceived risks and peer influences are amenable to intervention efforts targeting RSS. <p>[Social influence; social network intervention]</p>
Booth et al. (2011) ¹⁹	722 injection drug users	Experimental study (individually focused intervention vs. network	To evaluate the effects of an individual intervention vs. a	<ul style="list-style-type: none"> Both peer educators (OR, 0.32; 95% CI, 0.18–0.57) and network members (OR, 0.67; 95% CI, 0.54–0.82) in the

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Authors (years)	Sample	Design (data collection method)	Aims	Major findings [Components of social network characteristics] [Social influence; social engagement]
Latkin et al. (2009) ²⁰	414 networks with 1,123 participants in Chiang Mai, Thailand and Philadelphia, US	Randomized controlled trial (intervention consisted of six small group peer educator training sessions and two booster sessions delivered to the network index only)	To assess the efficacy of a network-oriented peer education intervention to promote HIV risk reduction among injection drug users and their drug and sexual network members in Chiang Mai, Thailand and Philadelphia, US.	<ul style="list-style-type: none"> The networks in the experimental condition in Philadelphia sustained statistically significant reductions in high-risk injection behaviors (OR, 0.56; 95% CI, 0.34–0.91). There were no significant effects associated with the intervention on risk behaviors in Thailand (OR, 1.27; 95% CI, 0.63–2.53). [Social network intervention]
Michael et al. (2002) ³⁷	708 women with breast cancer	Prospective, observational study (survey)	To examine prospectively the influence of social networks on health-related quality of life (HRQoL) among breast cancer survivors.	<ul style="list-style-type: none"> Socially isolated women were more adversely affected by breast cancer compared to the most socially integrated women ($p < 0.05$). Social integration is an important factor in future health-related quality of life among breast cancer survivors ($p < 0.05$). [Social support; social engagement]
Manuel et al. (2007) ⁵⁹	Baseline sample of a randomized clinical trial: 102 women	Cross-sectional study (survey)	To examine the structure and functioning of the social networks of women seeking conjoint treatment for an alcohol-use disorder.	<ul style="list-style-type: none"> Women with moderate/heavy drinking partners reported more drinking days but drank fewer drinks per drinking day than women with light drinking/abstaining partners ($t = -3.37$, 93 df, $p < 0.01$). There was a positive association between the number of drinkers in the social network and the participants' percentage of drinking days ($r = 0.30$, 100 df, $p < 0.05$). [Social network structure, social network function]
Oxman et al. (1992) ⁶⁷	1,962 non-institutionalized persons 65 years and older	Prospective, observational study (survey)	To examine the effect of social network characteristics and social support on depressive symptoms in the elderly.	<ul style="list-style-type: none"> Among the social support and network characteristics, loss of a spouse, adequacy of emotional support, and its change during 1982–1985 were significant factors of depressive symptoms ($R^2 = 0.345$, $p < 0.001$). [Social support]
Rosenquist et al. (2010) ⁶²	12,067 persons assessed at several time points between 1971 and 2003	Prospective, observational study (survey)	To examine (1) whether clusters of heavy drinkers and abstainers exist within the network; (2) whether a person's alcohol consumption behavior is associated with that of his or her social contacts; (3) the extent to which such associations depend on the nature and direction of the social ties (for example, friends of different kinds, siblings, spouses, coworkers, or neighbors);	<ul style="list-style-type: none"> Clusters of drinkers and abstainers were present in the network at all collected time points (50% connectivity; 95% CI, 40%–62%). When the index person's future alcohol consumption behavior, controlling for age, gender, education, and exam was regressed on the number of heavy drinking, moderate drinking, and abstaining contacts, each additional heavy drinking contact was found to significantly increase the likelihood that an index person's drinks heavily by 18% (95% CI: 11% to 25%, $p < 0.001$) and decreases the likelihood index person's

Authors (years)	Sample	Design (data collection method)	Aims	Major findings [Components of social network characteristics]
			and (4) whether gender affects the spread of alcohol consumption behavior (95% CI, 1.09–2.07) and (4) whether gender affects the spread of alcohol consumption behavior (95% CI, 1.09–2.07).	<ul style="list-style-type: none"> These clusters were not only due to a social selection process (homophily) among drinkers but also seem to reflect social influence. <p>[Social influence; homophily; social; network structure]</p>
Shaw et al. (2007) ³⁴	435 injection drug users in Canada	Cross-sectional study (personal interview)	To examine how individual and social network level variables were associated with syringe sharing among injection drug users.	<ul style="list-style-type: none"> Individuals' relationship to a risk network member (sex partner, OR, 15.3; 95% CI, 7.6–30.8; family member, OR, 3.4; 95% CI, 1.3–9.0) and difficulty of access to syringes (OR, 3.6; 95% CI, 1.3–9.9) were predictive of syringe sharing. Syringe sharing was strongly correlated with type and strength of social tie in dyadic relationships ($p < 0.20$). <p>[Social influence]</p>
Seo et al. (2012) ¹⁸	Ten social network analysis studies involving 28,263 adolescents	Systematic review	To examine whether peer selection or peer influence affects adolescents' smoking behavior. To examine whether there is a relationship between adolescents' smoking behavior and peer group social position.	<ul style="list-style-type: none"> Eight of ten reviewed studies indicate that peer selection or influence precedes adolescents' smoking behavior and intent to smoke. Adolescents who are identified as isolates are more likely to smoke and engage in risk-taking behaviors than others in the peer network structure. <p>[Social influence; homophily; social network position]</p>
Vogt et al. (1992) ³⁸	2,603 HMO members in 1970–71	Prospective, observational study (survey)	To examine the relationship between social network measures and coronary heart disease morbidity and mortality outcomes.	<ul style="list-style-type: none"> Social network measures (size, density, intensity, frequency, dispersion, homogeneity, reciprocity, durability, and multiplexity of social context) were strong predictors of both cause-specific and all-cause mortality among persons who had incident cases of ischemic heart disease, cancer, or stroke ($p < 0.01$). <p>[Social network structure; social network function]</p>
Wang et al. (1997) ⁵⁶	7,960 adolescents who participated in the study in 1989 and 1993	Prospective, observational study (survey)	To examine whether social (peer) influence predict adolescent smoking transition from non-smoking or experimental smoking to a more advanced state of smoking during a three-year span.	<ul style="list-style-type: none"> Smoking behavior of best friends was the only consistent and significant factor in predicting adolescent smoking progress to more advanced stages of acquisition (best male friends, OR, 1.50; 95% CI, 1.09–2.07) (best female friends, OR, 1.68; 95% CI, 1.20–2.36). <p>[Social influence]</p>