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Structural network position and performance of health leaders within an HIV prevention trial

Marta I. Mulawa[1], **Thespina J. Yamanis**[2], **Lusajo J. Kajula**[3], **Peter Balvanz**[4], and **Suzanne Maman**[4]

[1]Duke Global Health Institute, Duke University, Durham, NC

[2]School of International Service, American University, Washington, DC

[3]Department of Psychiatry and Mental Health, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania

[4]Department of Health Behavior, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC

Abstract

The effectiveness of peer leaders in promoting health may depend on the position they occupy within their social networks. Using sociocentric (whole network) and behavioral data from the intervention arm of a cluster-randomized HIV prevention trial in Dar es Salaam, Tanzania, we used generalized linear models with standardized predictors to examine the association between heath leaders' baseline structural network position (i.e., in-degree and betweenness centrality) and their 12-month self-reported 1) confidence in educating network members about HIV and gender-based violence (GBV) and 2) number of past-week conversations about HIV and GBV. As in-degree centrality increased, leaders reported fewer HIV-related conversations. As betweenness centrality increased, leaders reported greater number of conversations about GBV. Network position was not significantly associated with confidence in discussing either topic. Our results suggest that peer leaders who occupy spaces between subgroups of network members may be more effective in engaging their peers in sensitive or controversial topics like GBV than more popular peer leaders.

Keywords

Network position; popular opinion leader; HIV prevention; Tanzania

Correspondence: Marta Mulawa, Duke Global Health Institute, Duke University, 310 Trent Drive, Room 334, Durham, NC 27710, Phone: (919) 681-3540, marta.mulawa@duke.edu, marta.mulawa@gmail.com.

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ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study

INTRODUCTION

HIV prevention interventions that engage social networks have the potential to target and transform network-level factors associated with a number of important HIV-related behaviors. For example, researchers have demonstrated the association of social network-level factors (e.g. network size, structure, composition, and norms) with HIV testing (1, 2), injecting drug use (3, 4), intimate partner violence (5, 6), as well as risky sexual behaviors (7–9). Engaging social networks in HIV prevention interventions, therefore, provides an opportunity to target these network-level factors by leveraging the peer influence processes underpinning associations between network-level determinants and the HIV-related behaviors of network members (10).

Engaging network members as peer leaders (also called peer educators and peer change agents) has been a frequently used strategy to prevent HIV when working with social networks. For example, peer leaders have been used in interventions with school-based youth, substance users, sex workers, and men who have sex with men (11). Meta-analyses suggest that peer leaders are effective in increasing HIV knowledge and condom use as well as decreasing risk behaviors like syringe sharing among injection drug users (12). While the process of identifying peer leaders can include self-nomination, nominations by the target audience, identification of well-known individuals, selection based on self-described characteristics, or selection based on the occupation of formal leadership positions (e.g., clergy, elected officials) (12, 13), peer leaders can also be identified based on network theory. The most common way of using network theory to identify peer educators, called the popular opinion leader (POL) approach (14), involves identifying popular individuals, or individuals nominated by many network members. The intervention then trains them to model healthy behavior, increase awareness, share knowledge, and promote behavior change within their social groups. One seminal intervention using this approach promoted risk reduction among men who have sex with men (MSM) attending bars in US towns by having bartenders identify popular individuals who were then trained as opinion leaders to promote behavior change with their friends (15). The POL approach, grounded in the diffusion of innovations theory (16), is based on the premise that opinion leaders, by being encouraged to adopt a behavior early, model that behavior within their networks so that it is seen by others, becomes more normative, and ultimately ‘diffuses’ to others in a network (17). The rationale for identifying *popular* individuals is that they will have a particularly strong influence when modeling or promoting intervention messages because they occupy positions in their network characterized by prestige and visibility (13).

Trials of POL interventions for HIV prevention have had mixed results; the first two randomized trials, including one conducted with MSM within bars across 8 cities (18) and a subsequent trial conducted with women in 18 low-income housing developments (19), demonstrated positive intervention effects on behavioral outcomes. A subsequent multi-country randomized trial evaluating the approach did not find support for the intervention’s effect on HIV-related behavioral or disease incidence reduction (20), though additional analyses from this trial suggested that the intervention may have had differential effects among certain sub-groups of the populations (21, 22). More recent trials of the POL approach have demonstrated promising results in diverse settings, including the reduction of

HIV-related stigma in health care settings in China (23) and the promotion of HIV testing among MSM in Peru (24).

While little is known about the characteristics of effective vs. non-effective peer leaders from these existing trials, emerging research suggests that the effectiveness of peer leaders may depend on the position they occupy within their social networks. For example, a recent study that selected peer leaders based on differing positions in their social network found that individuals selected based on their popularity were less likely to be innovative when compared with those selected based on being in a high bridging position, a position characterized by connecting otherwise minimally connected subgroups (25, 26). This may be because popular individuals feel pressure to support prevailing norms in order to maintain their prominent position within the network (27). Individuals who occupy positions between subgroups of otherwise minimally connected peers, on the other hand, tend to have fewer friends in their network, and may as a result feel less pressure to support prevailing norms, and subsequently feel more freedom to innovate (25).

The aim of this paper is to describe the baseline structural network position (i.e., in-degree and betweenness centrality) of peer-nominated health leaders in a cluster-randomized HIV prevention trial in Dar es Salaam, Tanzania. We then examine the association between the baseline network position and the health leader's self-reported performance during the intervention, evaluated as part of the study's 12-month post-intervention launch assessment. To assess performance, we consider the health leader's self-reported confidence in educating fellow network members about HIV and gender-based violence (GBV) as well as their self-reported number of past-week conversations about these two topics. Based on theory and recent research (25, 27), we hypothesized that among health leaders trained in our intervention, increasing levels of in-degree centrality (i.e., increasing levels of popularity among network members) would be associated with decreasing levels of confidence and fewer amounts of past-week conversations about HIV and GBV. We also hypothesized that among health leaders trained in our intervention, increasing levels of betweenness centrality (i.e., increasing levels of serving as a gate-keeper between otherwise minimally connected groups) would be associated with increasing levels of confidence and greater amounts of past-week conversations about HIV and GBV.

METHODS

Setting

This study took place in Dar es Salaam, the commercial capital and city with the highest population density and the highest unemployment rate in Tanzania (28). Our research was conducted within four wards of Kinondoni Municipality, the most populated and impoverished of three municipalities in Dar es Salaam. Tanzania, similar to other sub-Saharan countries, is facing dual, interrelated epidemics of HIV and GBV (29). HIV prevalence in Dar es Salaam is 6.9%, higher than the national average of 5% (30). The Tanzanian DHS found that 44% of women age 15–49 years reported experiencing either physical or sexual violence in their lifetimes (31).

Overview

Our team implemented a health leadership intervention combined with a microfinance intervention to evaluate the effectiveness of this approach in reducing sexually transmitted infections and intimate partner violence perpetration. We evaluated this intervention in a cluster-randomized controlled trial, in which 30 social networks referred to as “camps” were randomly assigned to the intervention condition (32, 33). Camps are naturally-occurring social networks, mostly comprised of young men, that are formed by members to socialize and support one another (34). Camps tend to have an elected leadership structure (e.g., a chairman, secretary, treasurer) and members often meet daily to socialize or engage in activities like playing sports. The details for how camps were enumerated, evaluated for eligibility, randomly selected, and randomized to intervention or control condition have been described in the study protocol (32).

Selection of health leaders

In the intervention arm, we identified health leaders through a peer nomination process in which network members first discussed salient characteristics of leaders and subsequently nominated up to three members with these qualities. We tallied the nominations and invited those with the greatest number of nominations to serve as health leaders, seeking to engage 20% of members in each camp. In total, 180 eligible individuals were nominated as health leaders and 170 (94.4%) completed the required training.

Health leadership intervention

The health leadership intervention consisted of one initial one-week training and two, single-day booster training sessions held every 6-months post-training. The training provided health leaders with knowledge to address myths and misconceptions related to HIV transmission and prevention, condoms, violence and multiple sexual partnerships. A major component of the training was building skills in effective communication for social influence. The communication skills training was comprised of didactic lessons, demonstrations, and numerous opportunities for role-playing and the provision of feedback. The goal of the communication skills training was for health leaders to learn how to effectively engage their peers in conversations about sensitive topics, how to identify and address barriers to various HIV-related behaviors (e.g., practicing safe sex), how to counter negative viewpoints, how to use ‘I’ statements when talking with their peers about behavior, how to be better listeners, and how to model positive behavior choices for their peers. The training module on gender-based violence included several interactive activities that were designed to help the peer leaders clarify their own attitudes and values related to gender, violence and power and to help the leaders understand how violence affects women’s health and well-being. During the booster training sessions, health leaders discussed the successes and challenges they faced in implementing the strategies among their peers. Once health leaders were trained, they were asked to implement the strategies they learned among peers in the camps. Specifically, they were asked to incorporate the material they learned in the training into naturally occurring conversations that they were having with members of their camp. Health leaders received meals and a modest allowance for the training days to cover costs associated with transportation to get to and from the training venue.

Behavioral and social network assessment

We conducted behavioral assessments for the trial at baseline (prior to selection of health leaders) and 12-months post-intervention launch. A comprehensive sociocentric network assessment was integrated into the baseline assessment. Assessments were conducted by interviewers who used tablets programmed with a custom-designed CAPI (computer-assisted personal interviewing) instrument. The social network component of the assessment measured all social ties among network members by first displaying a complete camp roster associated with each participant and evaluating whether each person on the roster was known to the participant. Next, from a list of all known individuals in the camp, participants were asked to state whether each of these known members was a friend, acquaintance, or somebody they didn't get along with. From the list of friends (or acquaintances if <3 friends were identified), each participant was asked to identify his/her three closest friends within the camp. Informed consent was obtained from all individual participants included in the study. The study procedures and instruments were approved by [BLINDED FOR REVIEW] Institutional Review Board as well as the [BLINDED FOR REVIEW].

Analytic sample

Given our interest in understanding the association between network position and performance of health leaders, the analytic sample was restricted to health leaders for whom we had measures of performance. Specifically, of the 170 trained health leaders, 153 (90.0%) are included in this analysis because they participated in the 12-month assessment, answering questions about their performance as health leaders. However, network position was examined using data provided by all members in the 30 intervention camps (comprised of 621 men and 119 women) during the baseline sociocentric network assessment.

Measures

Measures included the two outcomes of interest, confidence and conversations about HIV/GBV, which were measured during the 12-month assessment. The two network position measures, in-degree centrality and betweenness centrality, as well as all other demographic control variables were measured using the baseline data. All predictor variables were standardized (i.e., rescaled to have a mean of 0 and a standard deviation of 1) prior to analysis.

Conversations—At the 12-month assessment, health leaders were asked to report the number of conversations they had about HIV and GBV in the past week. When asked about conversations about HIV, participants were reminded that this included talk of condom use, HIV testing, and not having multiple, concurrent sexual partners. Similarly, when asked about conversations about GBV, health leaders were reminded that this included talk of difficulties or violence between partners. Additionally, participants were told that gender-based violence includes verbally, physically, or emotionally trying to embarrass or hurt your partner, and arises from differences in power between men and women. Response options for the number of past-week conversations for both topics were: 0 = "none"; 1 = "1–4"; 2 = "5–9"; 3 = "10–15"; 4 = "more than 15."

Confidence—We also assessed the health leader's confidence in educating fellow network members about HIV and GBV at the 12-month assessment. Specifically, the health leaders were asked how confident they felt in educating their camp's members about HIV prevention. To assess GBV-related confidence, health leaders were asked how confident they felt in educating their camp's members about ways to prevent gender-based violence. Confidence in both topics was assessed using a 4-point Likert scale ranging from 1 = not confident, 2 = somewhat confident, 3 = confident, 4 = very confident.

Network Position—We used the igraph software package (35) in R to create two network position measures (i.e., in-degree centrality and betweenness centrality) based on the sociocentric (whole network) closest friendship networks enumerated within the 30 intervention networks at baseline. In-degree centrality, a measure of popularity, represented the number of network members that named the health leader as one of their three closest friends in the network. Betweenness centrality, a measure of serving as a "gate keeper" between minimally connected sub-groups, represented the number of paths that passed through each health leader.

Individual-level covariates—Individual-level covariates, assessed at baseline, included age (in years), highest level of education obtained, and marital history. We also assessed whether participants were sexually active at baseline and whether they had ever tested for HIV.

Network-level covariates—Network-level covariates included the network's size (i.e., number of men and women enumerated on camp rosters), percent of male members according to rosters, percent of all known ties characterized as friendship ties, as well as the density and reciprocity of friendship ties. Density of friendship ties represented the proportion of existing friendship ties over all possible ties between network members. Reciprocity of friendship ties represented the proportion of mutual friendship ties over all existing friendship ties. Given the heterogeneity of networks included in this study, these selected network-level covariates were included in the analyses to control for potential confounding since theory (36) and previous research findings suggest that these variables could be associated with structural network position as well as the performance/communication of health leaders. Specifically, structural network characteristics (e.g., network size, density, and reciprocity) are correlated with individual centrality measures (37, 38), and are also known to facilitate the diffusion and monitoring of norms within groups (39), thus would be expected to exert an influence on conversations between network members. The gender composition of networks has also been shown to shape friendship formation as well as norms that could influence communication patters (40). Similarly, the degree to which networks were comprised of friendship vs. acquaintance ties would be expected to influence the structure of the closest friendship networks as well as the conversations between network members. These network covariates were also calculated using the igraph software package in R.

Data Analysis

We first used descriptive statistics to assess the composition and structural characteristics of the camp-based social networks. Next, we used descriptive statistics to assess the characteristics of the health leaders, including their structural network position. To examine the associations between these network positions and performance as a health leader, controlling for individual-level and network-level covariates while also controlling for the clustered structure of our data, we fit general linear models using generalized estimating equations (GEE) through the GENMOD procedure in SAS software Version 9.4 (41). GEE models are often used to analyze correlated response data, which can arise when there is a clustered or multi-level structure to the data (e.g., participants nested within “camps”) (42). Our models specified an exchangeable working correlation structure, the most commonly made assumption for correlations within clusters (43). Models were run separately for all four outcomes of interest (i.e., confidence in talking about HIV, confidence in talking about GBV, number of past-week conversations about HIV, and number of past-week conversations about GBV).

RESULTS

Characteristics of camp-based social networks

The characteristics of the 30 camp-based social networks in the intervention arm of this cluster-randomized trial are presented in Table 1. Networks had an average of 31.9 members and on average, 82.6% of the networks were comprised of male members. The social networks contained on average 438.4 known relationships and most (73.8%) of the known ties were friendship ties. The networks were closely connected, with an average density of 0.3 among all friendship ties and 0.1 among closest friendship ties. The average reciprocity was 0.3 among all friendship ties and 0.2 among closest friendship ties. For every two members with a mutual friend, there was a 60% chance that they would also be friends (average transitivity among friendship ties = 0.6) and for every two members with a mutual closest friend, there was a 20% change that they would also be closest friends (average transitivity among closest friendship ties = 0.2). The closest friendship networks of two prototypical camps are depicted in Figure 1.

Participant Characteristics

The characteristics of the 153 health leaders are presented in Table 2. The vast majority (85.6%) of the health leaders were men and the mean age was 26.3 years. The majority (54.9%) had a primary school education or less, 10.5% finished some secondary school, and 34.6% completed secondary school or more. While most health leaders (70.6%) had never been married, the vast majority (92.8%) were sexually active at baseline. More than half (61.4%) had ever tested for HIV during the baseline assessment.

The mean in-degree centrality of health leaders was 3.6 (std. dev. 3.6). This means that on average, health leaders were named as “one of three closest friends” by under 4 other network members. The mean betweenness centrality was 49.6 (std. dev. 81.4). Figure 1 visually depicts a health leader with a high level of in-degree centrality as well as a health leader with a high level of betweenness centrality within the two prototypical camps.

The average level of confidence was 3.4 (std. dev. 1.0) regarding educating peers about HIV prevention and 3.4 (std. dev. 0.9) regarding educating peers about ways to prevent gender-based violence (range 1–4). The average number of past-week conversations reported was 1.7 (std. dev. 1.4) regarding HIV and 1.5 (std. dev. 1.4) regarding gender-based violence (range 0–4).

Network position and confidence in talking about HIV and GBV

There was no significant association between in-degree centrality and self-reported confidence in engaging peers about HIV or gender-based violence, though the direction of both relationships was positive (Table 3). Similarly, there was no significant relationship between betweenness centrality and confidence in engaging peers in conversations about HIV or GBV, though the direction of this relationship was negative for both.

For both HIV and GBV topics, female health leaders reported significantly lower levels of confidence in educating their fellow network members compared to their male counterparts ($\beta = -0.52$, $p = 0.05$; $\beta = -0.72$, $p < 0.001$, respectively). Neither age, marital history, being sexual active, or having tested previously for HIV were significantly associated with self-reported confidence in educating fellow network members about either HIV or GBV. Increasing level of completed education, on the other hand, was positively associated with increasing confidence in discussing GBV with fellow network members ($\beta = 0.16$, $p = 0.03$). Reporting an increasing number of conversations about GBV was also associated with increasing levels of confidence in educating network members on the topic ($\beta = 0.10$, $p = 0.02$). Neither education nor number of conversations about HIV were significantly associated with confidence in educating network members about HIV-related issues.

Of the network-level covariates included in the models, two were significantly associated with confidence in educating network members about HIV or GBV. As the percent of friendship ties increased, health leaders reported lower levels of confidence in educating their peers about HIV ($\beta = -0.13$, $p = 0.04$). As the reciprocity of friendship ties increased, health leaders reported lowers levels of confidence in educating their peers about both HIV ($\beta = -0.58$, $p = 0.02$) and GBV ($\beta = -0.46$, $p = 0.04$). The relationship between the other network-level covariates and confidence in educating network members about either topic did not reach statistical significance.

Network position and number of past-week conversations about HIV and GBV

As reported in Table 4, increasing in-degree centrality was associated with fewer number of conversations about HIV ($\beta = -0.18$, $p = 0.02$), after controlling for individual-level and network-level covariates. Similarly, increasing in-degree centrality was marginally associated with fewer number of conversations about GBV ($\beta = -0.16$, $p = 0.06$). Increasing betweenness centrality was significantly associated with greater numbers of conversations about GBV ($\beta = 0.15$, $p = 0.04$). While there was no statistically significant association between betweenness centrality and conversations about HIV, the trend of this relationship was also positive.

With regard to HIV, female health leaders reported fewer past-week conversations with their fellow network members compared to male health leaders ($\beta = -0.94$, $p = .005$). None of the

other demographic covariates (age, education, marital history, being sexual active, or having tested previously for HIV) were significantly associated with past-week conversations about either HIV or GBV. Increasing confidence in educating networks members about GBV was associated with more past-week conversations on the topic ($\beta = 0.22$, $p = 0.009$). Increasing confidence in educating network members about HIV-related topics was not significantly associated with past-week conversations about HIV.

Of the network-level covariates included in the conversation models, only network size was significantly associated with one of the outcomes. Specifically, as network size increased, health leaders reported more past-week conversations about HIV ($\beta = 0.31$, $p = 0.002$). This relationship was not significant for conversations about gender-based violence.

DISCUSSION

We found that as the popularity (i.e., in-degree centrality) of health leaders increased, health leaders reported having fewer conversations about HIV-related topics with their peers. While the association between increasing popularity and decreasing numbers of conversations about gender-based violence did not reach statistical significance ($p = 0.06$), the direction of this relationship was also in the hypothesized negative direction. It is notable that as in-degree centrality increases, health leaders actually have greater numbers of close friends with whom they could possibly engage in conversations. Yet, despite the increase in network members who named the health leader as a close friend, health leaders with increasing popularity reported fewer total conversations about HIV and GBV. Thus, our findings support the notion that popular individuals may be less likely to engage in controversial or sensitive activities like talking to their friends about ways to prevent HIV and/or GBV. This may be because they feel increased pressure to support prevailing norms, which do not include raising discussions about those topics, in order to maintain their position within the network. It has also been suggested that popular individuals do not have time to engage in intervention activities because their popularity burdens them with additional tasks and activities that are required to maintain their position (44, 45). This rationale may also help to explain our finding.

As we hypothesized, we also found that health leaders with increasing levels of betweenness centrality reported significantly increasing numbers of past-week conversations about gender-based violence with their fellow network members. While the association between increasing betweenness centrality and decreasing numbers of conversations about HIV was not statistically significant, the direction of this relationship was also in the hypothesized positive direction. These findings lend support to the notion that individuals with high betweenness centrality, those in gate-keeper positions between sub-groups that are otherwise minimally connected, may experience less peer pressure to behave in ways that support prevailing norms compared to individuals who are not in those positions. Because of this reduced pressure, health leaders with high levels of betweenness centrality likely felt more comfortable engaging in conversations about sensitive topics like the prevention of gender-based violence. Since these individuals tend to have fewer friendships to maintain, it has also been suggested that they have more time and can devote more energy to thinking strategically about how to best engage their peers in these conversations (45).

While the results for associations between in-degree centrality and betweenness centrality and number of past-week conversations about HIV and gender-based violence were largely consistent with our hypotheses, the associations between structural network position and confidence to educate peers, while not statistically significant, were in the opposite direction of our hypotheses. In other words, while health leaders with increasing levels of popularity reported *fewer* past-week conversations about HIV and marginally *fewer* number of conversations about GBV (as we hypothesized), the relationship between increasing popularity and confidence was *positive*. Similarly, while health leaders with increasing levels of betweenness centrality reported significantly *increasing* numbers of past-week conversations about gender-based violence (as we hypothesized), the relationship between increasing betweenness centrality and confidence was *negative*. This may be because occupying varying positions in a network may be associated with naturally-occurring personality traits (46), which may include confidence (or a lack thereof). Interestingly, increasing confidence in educating peers about GBV was significantly associated with reporting more GBV-related conversations. Since the relationship between network position and confidence in educating peers about HIV and gender-based violence was not in the hypothesized direction, confidence is likely not a mediator of the relationship between network position and engaging in conversations about these topics. Future research should explore other potential mediators of the relationship between network position and actually engaging in intervention-related conversations with network members. Identifying the mediators of peer-driven interventions was also noted as an important area of future research in a systematic review of HIV/AIDS-related peer-based interventions in sub-Saharan Africa (47).

While many of our findings were consistent for both HIV and gender-based violence, some notable differences were observed. In addition to the fact that increasing levels of betweenness centrality were associated with reporting more conversations about GBV, but not HIV, increasing confidence in educating peers about GBV was significantly associated with more GBV-related conversations, a pattern that was not significant for HIV-related topics. This may speak to the difference inherent in discussing HIV vs. gender-based violence within these predominantly male social groups. The frequency of past-week conversations about HIV were also higher than those about GBV. While more research is needed to understand these findings, it is possible that health leaders were generally more comfortable discussing HIV-related topics (e.g. providing information on where to get tested) than challenging the entrenched gender norms and the root of gender-based violence. As a result, engaging in discussions about GBV may have required more effort and confidence than talking about HIV. This could be a result of the fact that while HIV testing and other HIV prevention activities have been provided by the Tanzanian government, private sector and other non-governmental organizations for a number of years, efforts to systematically address gender and gender-based violence within community settings are more nascent (29). Indeed qualitative work conducted within camp-based peer networks has highlighted the ways in which these networks pressure members to conform to certain gender norms that were often more traditional in nature (48).

Our findings having implications for future research and interventions. In terms of the intervention implications, our results suggest that strategically recruiting and supporting

individuals with greater levels of betweenness centrality may be a way to maximize the effectiveness of peer-based intervention approaches. This may be particularly relevant for interventions hoping to transform deeply-held network norms, like those related to gender and gender-based violence. Focusing intervention efforts on individuals with high betweenness centrality has been recommended by other researchers as well. Researchers examining networks of younger black men who have sex with men in Chicago reported that bridging network position, and not risk behavior, was associated with HIV status (49). Based on these findings, and noting that bridging individuals may be more receptive to behavior change and more innovative as opinion leaders, the researchers recommended future interventions evaluate the effectiveness of identifying individuals occupying these bridging network position. Another study with injecting drug users in Lithuania found that betweenness centrality was associated with HIV prevalence, highlighting the importance of engaging people with high betweenness centrality as peer educators in HIV prevention interventions (50). Strategically recruiting individuals who occupy certain positions in their networks in line with a recent review of social network strategies to prevent HIV that recommended that future network interventions "optimally use the power of social networks to reduce HIV transmission" (10). To fully understand the role of network position in influencing health leader's performance in HIV prevention trials, however, research that longitudinally examines the co-evolution of social networks and intervention-related communication patterns is needed.

Strengths and Limitations

A key strength of our study is our cluster-randomized study design that gave us the opportunity to examine the effects of network position on peer leader performance within a random sample of 30 diverse networks that had been randomly assigned to the intervention condition. Our sociocentric network assessment additionally allowed us to examine the network position of health leaders from a whole network perspective while also controlling for structural network covariates, like density and reciprocity that are known to shape norms and behaviors of network members. Additionally, we assessed network position prior to the identification of health leaders and used 12-month post-intervention launch data to evaluate the health leader's performance, allowing us to be confident in the temporality of these associations.

However, our findings should also be considered in light of their limitations. First, our outcome measures were self-reported by the health leaders, which may have been inaccurate due to potential recall and/or social desirability biases. Additionally, we used a one-item question to measure leaders' confidence in educating their peers about the intervention topics. This measure may have been less reliable and more prone to measurement error than a multi-item scale designed to more comprehensively measure leaders' confidence or self-efficacy in specific aspects of engaging peers in conversations. Additionally, since a large proportion of participants endorsed the maximum confidence score, there may have been a ceiling effect when examining the relationships between network position and self-reported confidence using this measure. Furthermore, our measure of past-week conversations was purely quantitative (i.e., how many conversations did you have?) and did not assess the content, duration, or quality of those conversations. Furthermore, it is not possible to know

whether a health leader reported multiple conversations with the same individual or a single conversation with several individuals. We also acknowledge that self-reported number of past-week conversations is not a direct measure of the leaders' effectiveness in ultimately spurring behavior change in their peer. Furthermore, to ease comparisons across networks of varying size, we chose to measure network position based on the closest friendship networks. While this allowed us to examine structure based on meaningful friendship ties, the outcomes measures were based on the entire network. Had we assessed number of past-week conversations with closest friends, our findings may have been different. Finally, our data come from men who are members of camp-based social networks in Dar es Salaam, and as such, may not be generalizable to other networks of men in sub-Saharan African settings.

CONCLUSION

Our study demonstrates the importance of network structure in the implementation of HIV and gender-based violence interventions. We found that as in-degree centrality, or popularity, increased, health leaders in this cluster-randomized HIV prevention trial reported fewer conversations about HIV-related topics. On the other hand, as betweenness centrality, a measure of serving as a "gate keeper" between minimally connected sub-groups, increased, health leaders reported greater number of conversations about gender-based violence. Our results suggest that peer leaders who occupy spaces between sub-groups of network members may be more effective in engaging their peers in sensitive or controversial topics than more popular peer leaders.

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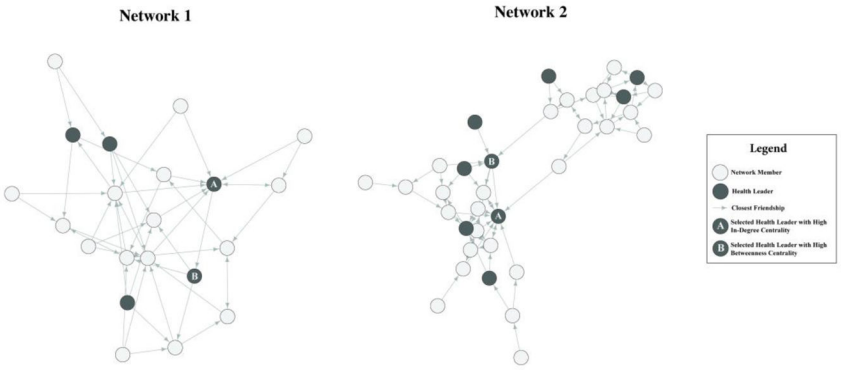

Figure 1.

Closest friendship networks of two prototypical camps, with health leaders highlighted. Within each network, selected Health Leader A has a high level of in-degree centrality whereas selected Health Leader B has a high level of betweenness centrality.

Table 1

Characteristics of camp-based social networks (n = 30)

Characteristic	Mean	SD	Range
Overall network size (male and female)	31.9	12.5	20 – 77
% Male	82.6	14.9	47.6 – 100
Number of all known ties	438.4	328.3	71 – 1722
Breakdown of known ties			
% friendship ties	73.8	21.6	26.5 – 100
% acquaintance ties	25.3	21.2	0.0 – 73.5
% negative ties	0.8	1.2	0.0 – 4.1
Density			
Friendship	0.3	0.2	0.1 – 0.6
Closest friendship	0.1	0.0	0.0 – 0.1
Reciprocity			
Friendship	0.3	0.1	0.1 – 0.6
Closest friendship	0.2	0.1	0.0 – 0.4
Transitivity			
Friendship	0.6	0.2	0.2 – 0.9
Closest friendship	0.2	0.1	0.0 – 0.4

Table 2

Sample Characteristics (n = 153)

Variables	% (n) or Mean (SD)
Male Gender	85.6 (131)
Age in years (mean)	26.3 (7.1)
Education	
Primary school or less	54.9 (84)
Some secondary school	10.5 (16)
Secondary school completed or more	34.6 (53)
Marital history	
Never married	70.6 (108)
Ever married	28.8 (44)
Sexually active	92.8 (142)
Ever tested for HIV	61.4 (94)
In-degree centrality (mean)	3.6 (3.6)
Betweenness centrality (mean)	49.6 (81.4)
Confidence in discussing HIV	3.4 (1.0)
Confidence in discussing GBV	3.4 (0.9)
Number of past-week conversations about HIV	1.7 (1.4)
Number of past-week conversations about GBV	1.5 (1.4)

Table 3

Results for the model of structural network position on health leaders' confidence in educating network members about HIV and gender-based violence (GBV)

	HIV		GBV	
	β	**95% CI**	***β***	**95% CI**
Intercept	3.41***	(3.1, 3.72)	3.39***	(3.17, 3.62)
Individual-level covariates				
Gender	−0.52*	(−1.03, −0.01)	−0.72***	(−1.13, −0.31)
Age	0.01	(−0.16, 0.19)	0.00	(−0.17, 0.17)
Education	0.16	(−0.01, 0.34)	0.16*	(0.02, 0.31)
Marital history	0.06	(−0.07, 0.18)	0.07	(−0.09, 0.22)
Sexually active	0.06	(−0.14, 0.25)	0.10	(−0.07, 0.27)
HIV testing	0.04	(−0.16, 0.23)	0.01	(−0.18, 0.20)
Conversations about HIV/GBV	0.02	(−0.08, 0.13)	0.10*	(0.02, 0.18)
Network-level covariates				
Network size	−0.06	(−0.19, 0.08)	0.00	(−0.12, 0.11)
Percent of male members	0.01	(−0.12, 0.15)	−0.11	(−0.23, 0.01)
Percent of friendship ties	−0.13*	(−0.26, −0.01)	−0.07	(−0.19, 0.05)
Density of friendship ties	0.38	(−0.08, 0.85)	0.37	(−0.05, 0.78)
Reciprocity of friendship ties	−0.58*	(−1.06, −0.11)	−0.46*	(−0.88, −0.03)
Structural network position				
In-degree centrality	0.11	(−0.02, 0.24)	0.03	(−0.09, 0.14)
Betweenness centrality	−0.02	(−0.12, 0.09)	−0.03	(−0.11, 0.06)

* p<0.05;

** p<0.01;

*** p<0.001

Table 4

Results for the model of structural network position on health leaders' reported number of past-week conversations about HIV and gender-based violence (GBV)

	HIV		GBV	
	β	**95% CI**	***β***	**95% CI**
Intercept	1.72***	(0.94, 2.49)	0.82**	(0.26, 1.38)
Individual-level covariates				
Gender	−0.94**	(−1.6, −0.28)	−0.45	(−1.06, 0.15)
Age	0.00	(−0.28, 0.27)	0.01	(−0.29, 0.31)
Education	0.15	(−0.06, 0.37)	0.10	(−0.08, 0.27)
Marital history	0.06	(−0.19, 0.31)	0.05	(−0.26, 0.36)
Sexually active	−0.09	(−0.37, 0.19)	0.00	(−0.30, 0.29)
HIV testing	0.17	(−0.05, 0.40)	0.09	(−0.17, 0.35)
Confidence in Educating	0.04	(−0.19, 0.27)	0.22**	(0.06, 0.38)
Network-level covariates				
Network size	0.31**	(0.11, 0.50)	0.13	(−0.08, 0.33)
Percent of male members	−0.09	(−0.38, 0.19)	−0.10	(−0.36, 0.16)
Percent of friendship ties	−0.06	(−0.28, 0.16)	−0.04	(−0.25, 0.17)
Density of friendship ties	−0.03	(−0.68, 0.62)	−0.18	(−0.81, 0.45)
Reciprocity of friendship ties	0.20	(−0.55, 0.96)	0.33	(−0.41, 1.07)
Structural network position				
In-degree centrality	−0.18*	(−0.34, −0.03)	−0.16	(−0.32, 0.01)
Betweenness centrality	0.05	(−0.09, 0.19)	0.15*	(0.00, 0.29)

* p<0.05;

** p<0.01;

*** p<0.001