Identifying Asymmetric and Symmetric Ties Among National Network of Local Health Departments

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Social Network Analysis

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Background

Local health departments (LHDs) are fundamental to a community since they assess community health needs and implement necessary programs that enable individuals to lead healthier lives within their communities (NACCHO, 2015; Brownson et al., 2007). LHDs provide a range of services, such as communicable and infectious disease surveillance, tuberculosis screening, adult and child immunizations, maternal and child health services, and activities related to emergency preparedness (NACCHO, 2015). The purpose of these services is to protect and improve the health and well-being of individuals (NACCHO, 2015). A LHDs ability to disseminate and implement health information and services is contingent upon several factors, such as the organizational and economic characteristics, as well as the political climate (Brownson, Fielding, & Maylahn, 2009; Gyllstrom et al., 2015; Harris et al., 2012; Harris, 2013).

According to the National Association of County and City Health Officials (NACCHO) (2015), the staff size of LHDs have reduced drastically due to budget cuts. As a result, state and local health departments have eliminated an estimated 51,000 jobs in 2008, and an additional 38 percent of LHD staff in 2013 (NACCHO, 2015). Such reductions impede LHDs ability to implement evidence-based public health (EBPH) strategies, which can result in a high opportunity cost for communities (Brownson, Fielding, & Maylahn, 2009; Harris, 2013). Given the EBPH barriers that are common among LHDs, creating partnerships with knowledgeable and skilled professionals in other LHDs can assist in the dissemination process as well as mitigate and prevent adverse health outcomes by exchanging successful programming and surveillance techniques (Harris, Luke, Burke, & Mueller, 2008; Harris et al., 2012; Harris, 2013).

In 2013, Harris conducted a social network analysis using data from the 2010 National Association of County and City Health Officials Profile of Local Health Departments profile study to investigate the strength and characteristics of ties between LHDs. Since dissemination and implementation of EBPH strategies is not a feasible option for many LHDs, it is important to understand the network's communication ties between LHDs as they can be informative of which LHDs are prominent drivers of information between LHDs (Harris, 2013). Based on Rogers concept that new ideas are broadcasted through communication channels (2003), Harris applies the four necessary elements for the diffusion of communication in understanding the network of LHDs: "(1) the idea; (2) an adopter; (3) a non-adopter; and (4) a communication channel linking the adopter and non-adopter" (2013).

Ties within the network of LHDs were characterized as either strong or weak based on whether the ties are mutual or asymmetrical. Harris (2013) defined ties within the network of LHDs as strong if the relationship between two LHDs is mutual. A tie was considered weak, or asymmetric, if only one LHD noted another LHD as a partner or collaborator (Harris, 2013). Although weak ties usually exist between adopters and non-adopters, weak ties are also able to provide new information to an organization or group and act as a bridge between network subgroups (Granovetter, 1973; Harris, 2013). Strong ties, however, are typically more closely linked as they share similar characteristics, information, and programming between LHDs. The existence of such strong ties develops over time and creates trust between LHDs (Granovetter, 1973; Harris, 2013). Strong ties between LHDs can be influential in facilitating and encouraging other closely linked LHDs to implement similar and successful programs (Harris, 2013).

The goal of this social network analysis is to utilize similar methods used in *Communication Ties Across the National Network of Local Health Departments* (Harris, 2013) to examine a national network of LHDs. Data from 2016 National Association of County and City Health Officials Profile of Local Health Departments profile study was used to assess characteristics that create stronger or weaker ties, as they may be influential within a network of LHDs in the dissemination and implementation of programs. An understanding of how the national network of LHDs has changed since 2010 can assist policymakers and public health practitioners in creating future strategies for developing an interconnected network. In addition, the information from the network analysis can be used to strengthen the flow of dissemination and implementation programming strategies between LHDs. As part of the social network analysis, a statistical model was developed to assess characteristics associated with strong and weak ties within a network of LHDs.

Methods

Data Source

The data used for this study was obtained from the 2016 National Association of County and City Health Officials Profile of Local Health Departments profile study, which was conducted by the National Association of County and City Health Officials (NACCHO). Approximately, 2533 LHDs from 48 states and Washington DC participated in the NACCHO study. Rhode Island and Hawaii were excluded from the NACCHO profile study as they only have state health departments and no local health departments (NACCHO, 2015). The response rate for the 2016 NACCHO profile study was 76 percent, or 1925 participating LHDs.

Measures

In the NACCHO network of LHDs, asymmetric ties were non-reciprocal links between one LHD and another. When both LHDs identified one another as a collaborator, they were linked as a mutual tie (Granovetter & Granovetter, 1983; Harris, 2013).

As part of the social network analysis, descriptive, visual, and statistical network analyses were conducted. For descriptive measurements, we calculated density, distribution of indegree, distribution of outdegree, and the percentage of bilateral ties. Density was defined as the number of observed edges divided by the maximum number of possible edges, which indicates the interconnectedness of the network (Luke, 2016). In a directed graph, the indegree refers to the number of ties going into a node and the outdegree refers to the number of ties outgoing from a node (Krackhardt, 1992). Usually, the sum of total indegree is equal to the sum of total outdegree.

A visual analysis was conducted using the national network of LHDs as well as using LHDs in three states, Missouri, Illinois, and Iowa, to understand how neighboring states interact with one another. We calculated the betweenness centrality of these three states, which takes into account directed ties (Luke, 2012). Finally, we identified key LHDs with higher betweenness centrality that played an important role in the interconnection of states.

Exponential random graph models (ERGMs) (Robins, Pattison, Kalish, & Lusher, 2007) were used to estimate the potential interconnection between any two LHDs. In this study, we used four models to predict the likelihood of two LHDs being linked based on asymmetric ties and mutual ties. The baseline, null model was built using only the edges of the network as the independent variable. The additional statistical models used for this analysis were compared to the baseline, null model to examine whether models containing additional variables were a better-fit at explaining the data. Model 1 was used to predict only the asymmetric ties by adding the independent variables: state, population size, full-time equivalents (FTEs) staff, jurisdiction type, top executive tenure, nutrition program, and tobacco prevention program. For the FTEs calculation, a full-time employee was counted as 1, and a half-time employee was counted as 0.5. Model 2 used the same variables as model 1 to predict both asymmetric ties and mutual ties. Model 3 (the dyadic-dependency model) included geometrically weighted edgewise-shared partnerships (GWESP), which measured the effect of local clustering on the possibility of interconnections. In addition, the Akaike information criterion (AIC) measures of model fit was used to assess the best-fitting model.

Software

Analyses were generated in R 3.3.2 using three packages: Igraph (Csárdi & Nepusz, 2006), Statnet (Handcock, Hunter, Butts, Goodreau, & Morris, 2008), and ERGM (Hunter, Handcock, Butts, Goodreau, & Morris, 2008).

Results

Among all participants, 1397 named (71.9%) other LHDs that they collaborated with. Of these, 75 LHDs were excluded due to the incorrect listing of a LHD name (e.g., state health departments, community groups, and vague nominations) or LHDs named their own LHD as a collaborator. Due to missing vertex attribute values, 533 LHDs were removed from the network. After excluding incorrect and missing data, 1366 LHDs and 3595 communication links were included in the analysis. (Appendix A).

The overall density of the network was 0.0019, which means there were nineteen links of every 10,000 possible. This low density value indicates that communications between LHDs were very limited. The mean indegree was 2.63 (SD = 2.64). The mean outdegree was 2.63 (SD = 1.68). This network had 1262 mutual ties between 1366 LHDs. The percentage of mutual ties was 35.1 percent. Of them, most were between LHDs in the same state. For example, there were only a few connections across between Missouri, Illinois, and Iowa (Appendix D). The network densities of Missouri, Illinois, and Iowa were 0.038, 0.043, 0.036 respectively, which were much higher than the overall network density. The betweenness centrality values indicate that LHDs with ties across state lines were more likely to have higher betweenness centrality.

Model 2 had the best fit which demonstrates that LHDs in the same state, serving similar populations, and similar FTEs would be more likely to build an asymmetric, or weak tie (Appendix B). In other words, LHDs sharing similar organizational characteristics were more likely to have weak ties. However, being in the same state was the only predictor of a mutual tie (Appendix B). As a result, two health departments in the same state are significantly more likely to have both asymmetric and mutual ties between them compared to two health departments not in the same state (Appendix B).

Discussion

In the national network of LHDs, asymmetric, or weak ties were more likely between LHDs with similar population sizes and FTEs. Sharing the same state was considered both a weak and strong predictor for LHDs, which indicates there are other characteristics beyond sharing the same state that contribute to having a strong or weak tie. Local health departments can utilize the results of this analysis to expand their social networks. Departments with the highest betweenness centrality measures are able to control the flow of information between subgroups and are more likely to link two states within the national network of LHDs. In an effort to expand effective dissemination and implementation strategies, LHDs should create connections with other LHDs with different population sizes and full-time equivalent staffing. The proportion of mutual, or strong ties within the network of LHDs was significantly smaller than the proportion of weak ties suggesting that LHDs can create mutual relationships with other LHDs with varying population sizes and full-time equivalent staffing. Through these mutual relationships, LHDs can also increase dissemination and implementation between LHDs due to existing strong ties.

This analysis had several limitations. The NACCHO profile study was not intended to examine the dissemination and implementation of information and programs between LHDs, so we cannot confirm the results of our analysis reflect the true nature of the network of LHDs. Additionally, the NACCHO profile study requires top executives at LHDs to complete the survey modules and name other LHDs they collaborate with which suggests the possibility that other staff members who did not fill out the modules may have collaborated with other LHDs. This would result in underreporting of collaborations between LHDs to exchange information regarding programming.

Moreover, the top executives at LHDs were asked to self-report collaborations with other LHDs, which could result in recall bias, missing data, listing their own LHD, or the incorrect listing of a LHD name. Top executives who listed their own LHD as a collaborator may have misunderstand the survey question or did not collaborate with other LHDs. The incorrect listing of a LHDs name could also be due to infrequent communication between LHDs.

Due to the limitations in time and the amount of data, we were unable to correct incorrectly listed LHD names, which resulted in the deletion of these LHDs. Further investigation into the location of LHDs based on their jurisdiction could allow for the identification of missing or incorrectly listed LHDs. Geographic spatial software was not used for this analysis, which could have assisted in the identification of missing or incorrectly listed LHD names. In addition, geographic spatial software could be used to further understand the communication between LHDs within and between states. Local health departments within the same state may not have communication with other LHDs within the same state due to distance. However, LHDs that are in different states, but in close proximity may have increased communication and exchange of information. The use of such software can enhance understanding of communication within a network of LHDs.

Conclusion

As LHDs endure challenges in communication and

References

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Appendix A:

Table 1. Local Health Department network characteristics (n= 1397), n (%) or Median

Characteristics	LHDs, *n* (%)
Population	
<25000	474(33.9)
25000-49999	306(21.9)
50000-99999	233(16.7)
100000-499999	295(21.1)
>=500000	89(6.4)
FTE	
0-25	822(58.8)
25.01-50	221(15.8)
50.01-100	181(13.0)
≥100	173(12.4)
Jurisdiction type	
City	193 (13.8)
City-county	4 (0.3)
County	1024 (73.3)
Multi-city	53 (3.8)
Multi-county	123 (8.8)
Top executive tenure (years)	
1-2	381(27.3)
3-5	345(24.7)
6-10	280(20.0)
≥11	391(28.0)
Missing data	
Names missing	25
Listed their own LHD	50
Missing survey response	586
Prevention programs	
Nutrition	
Yes	1065(76.3)
No	332(23.8)
Tobacco	
Yes	1058 (75.8)
No	339(24.3)

Appendix B:

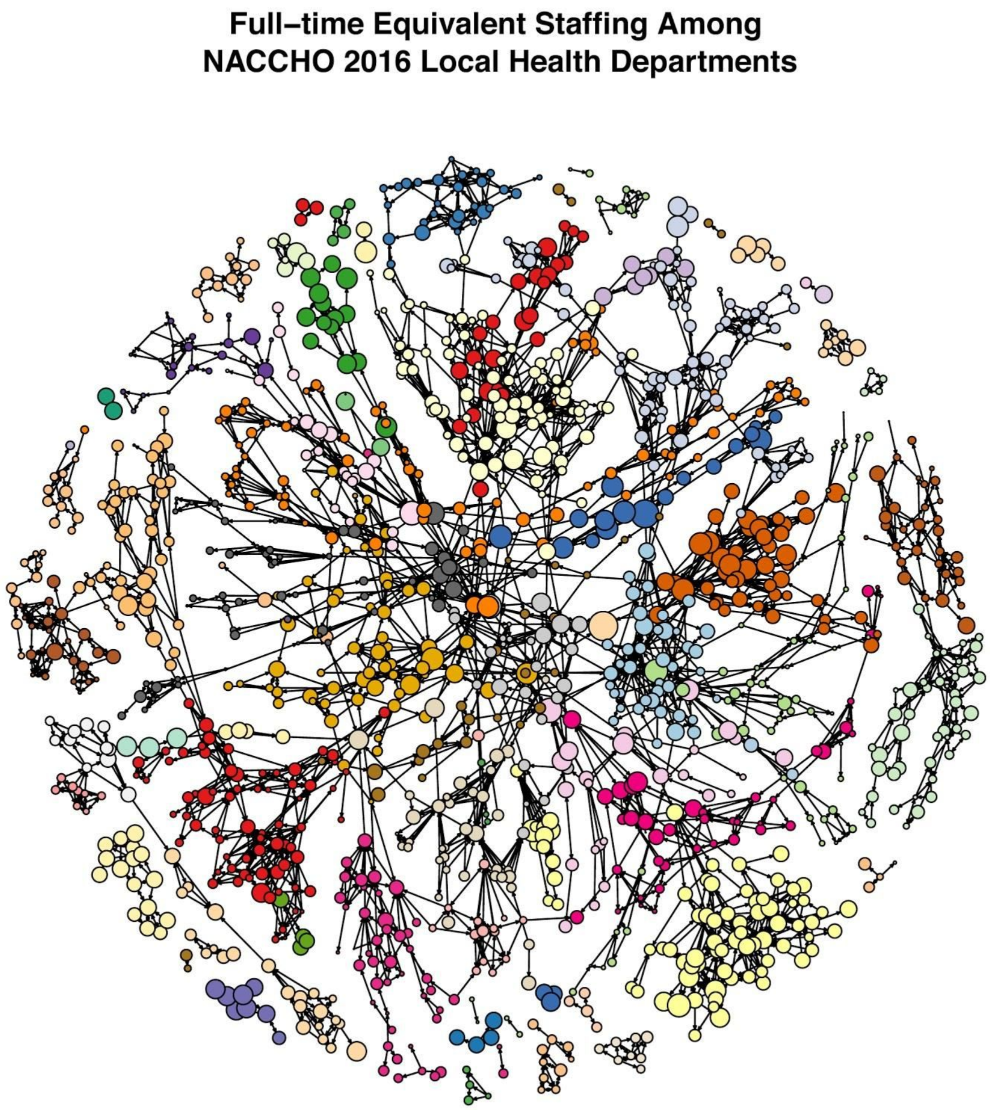
Table 2. Strong and weak tie predictors among local health department network, b (SE).

	Null		Model 1		Model 2		Model 3	
	b(SE)	p-value	b(SE)	p-value	b(SE)	p-value	b(SE)	p-value
Edges	-6.25(0.02)	**<0.001***	-5.67(0.04)	**<0.001***	-9.85(0.16)	**<0.001***	-9.74(0.15)	**<0.001***
Asymmetric								
State	--	--	4.26(0.05)	**<0.001***	6.34(0.11)	**<0.001***	5.67(0.12)	**<0.001***
Population Size	--	--	-0.08(0.05)	0.11	0.37(0.10)	**<0.001***	0.29(0.12)	**<0.02***
Full-Time Equivalents	--	--	-0.70(0.05)	**<0.001***	-0.22(0.09)	**<0.01***	-0.10(0.11)	0.36
Jurisdiction Type	--	--	-0.78(0.05)	**<0.001***	0.03(0.09)	0.71	0.12(0.11)	0.87
Top Executive Tenure	--	--	-0.50(0.06)	**<0.001***	0.17 (0.10)	0.08	0.08 (0.08)	0.32
Nutrition	--	--	-0.77(0.05)	**<0.001***	0.11(0.10)	0.28	-0.12(0.11)	0.89
Tobacco	--	--	-0.67(0.05)	**<0.001***	0.09(0.09)	0.32	0.08 (0.12)	0.46
Symmetric								
State	--	--	--	--	15.21 (1.00)	**<0.001***	12.65(0.96)	**<0.001***
Population Size	--	--	--	--	1.17(0.74)	0.11	0.87(0.28)	**<0.002***
Full-Time Equivalents	--	--	--	--	0.14(0.62)	0.82	0.04(0.46)	0.93
Jurisdiction Type	--	--	--	--	0.51(0.58)	0.38	0.66(0.51)	0.20
Top Executive Tenure	--	--	--	--	0.28(0.60)	0.64	-0.22(0.56)	0.69
Nutrition	--	--	--	--	0.03(0.55)	0.96	-0.35(0.63)	0.58
Tobacco	--	--	--	--	-0.10(0.45)	0.82	0.41(0.38)	0.27
GWESP (α =0.2)	--	--	--	--	--	--	0.98(0.07)	**<0.001***
Model AIC	52,082		43,933		38,102		38,170	

*Note: boldface indicates significance. *p<0.05*

Appendix C:

Figure 1.



Appendix D:

Figure 2.