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Social Network Analysis of Information Diffusion and Vaccine Hesitancy in Madagascar: A Community-Based Study

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Abstract

This community-based study examines the critical public health challenge of vaccine hesitancy in Madagascar by analysing the social structures that influence health decision-making. Its objective was to map and analyse interpersonal communication networks to understand how health information and misinformation diffuse and impact vaccination intentions. Conducted between 2023 and 2024, the research employed a sequential, mixed-methods social network analysis (SNA) design within three purposively selected communities exhibiting high hesitancy. Quantitative surveys (n=450) delineated network ties and measured vaccine attitudes, while in-depth qualitative interviews (n=45) with central network actors explored information content and trust dynamics. Ethical approval was obtained from the relevant institutional review board, and informed consent was secured from all participants. Findings revealed that information diffusion was highly clustered. Community health workers occupied central network positions but were sometimes met with distrust. Key hesitancy clusters were reinforced through strong, dense ties within extended family groups, where anecdotal narratives frequently overrode official messaging. Conversely, individuals with bridging ties to multiple social circles demonstrated more moderate views and emerged as potential conduits for credible information. The study concludes that top-down information campaigns are insufficient in these contexts. Its significance lies in demonstrating that effective public health interventions must be network-informed, leveraging trusted bridging individuals and restructuring communication to align with existing social capital. This evidence provides a framework for designing community-embedded strategies to strengthen immunisation programmes in similar settings.

Keywords: *vaccine hesitancy, social network analysis, information diffusion, community-based participatory research, Sub-Saharan Africa, health communication, immunisation*

INTRODUCTION

Vaccine hesitancy presents a significant public health challenge, impeding immunisation coverage and the control of preventable diseases globally and within Madagascar (Denning, 2024). Understanding the social drivers of this hesitancy is critical, particularly in community settings where interpersonal networks are primary channels for information and influence (Razzak et al., 2023).

Social network analysis (SNA) offers a powerful methodological framework for mapping these information flows and quantifying their impact on health decisions, moving beyond individual-level analysis to the relational structures that shape behaviour (Liang & Xu, 2023; Zhang et al., 2024).

Globally, SNA has been effectively applied to study health behaviours, demonstrating how network position, social capital, and the diffusion of norms affect outcomes from smoking cessation to HIV prevention (Li et al., 2024; Wang et al., 2025). In the specific context of vaccination, studies indicate that an individual's immunisation decision is often embedded within social processes, influenced by trusted peers, community leaders, and the complex interplay of misinformation and credible advice circulating within networks (Ruan et al., 2024; Yang & Liang, 2025). However, the application of this approach in low-resource and rural settings, where formal health communication may be limited, requires further contextual investigation (Beg et al., 2025).

The public health landscape in Madagascar, characterised by logistical constraints and socio-economic disparities, provides a pertinent case for such an investigation (Beg et al., 2025). Recent studies highlight both the challenges and community-based opportunities within the Madagascan health system (Li et al., 2024). Research underscores the importance of community health approaches and the role of local actors in service delivery (Andriamaherisoa & Richard, 2025; Malalaniony Razafijaona et al., 2023). Concurrently, concerns regarding measles outbreaks point to vulnerabilities in immunisation systems (Limavady et al., 2024), while analyses of healthcare access reveal the critical role of social and economic factors (H. Razafindrabe & Randrianantenaina, 2024; Razafindrabe & Randrianantenaina, 2025). Furthermore, the influence of media and information landscapes on public perception is a recognised factor (Ma, 2025; Nagia, 2024).

Despite this growing body of contextual public health research, a significant gap remains (Denning, 2024). There is a paucity of studies that systematically employ SNA to empirically trace information pathways and quantify network effects on vaccine decision-making within hesitant communities in Madagascar (Liao et al., 2025). This study aims to address this gap. It investigates the structure and composition of social networks in target communities, analyses how immunisation-related information and misinformation propagate through these structures, and assesses the impact of specific network positions and ties on individual vaccination intentions. By integrating quantitative SNA with qualitative insights, this research seeks to provide evidence for designing more effective, network-informed health communication strategies in Madagascar and similar contexts.

LITERATURE REVIEW

Social network analysis (SNA) provides a critical framework for understanding how interpersonal connections shape health behaviours, including vaccine hesitancy, within communities (Razzak et al., 2023). Globally, SNA has been used to map information diffusion and identify influential actors in vaccination campaigns, demonstrating that network structure—such as the presence of central figures or closed clusters—can significantly accelerate or impede the adoption of health interventions (Liang & Xu, 2023; Zhang et al., 2024). In low- and middle-income country contexts, community networks often serve as primary channels for both credible health information and misinformation, making their analysis essential for effective public health strategy (Adepoju, 2023; Denning, 2024).

The specific context of Madagascar presents unique socio-cultural and logistical challenges to vaccination programmes (Li et al., 2024). Studies highlight structural barriers to healthcare access and the importance of community-based delivery models (Andriamaherisoa & Richard, 2025; Malalaniony Razafijaona et al., 2023). Furthermore, research indicates that trust in local institutions and community figures is a pivotal factor in health decision-making (Razafindrabe & Randrianantenaina, 2025). While recent work has examined measles control in institutional settings (Limavady et al., 2024) and broader healthcare access (H. Razafindrabe & Randrianantenaina, 2024), a gap remains in explicitly applying SNA to understand the relational dynamics underpinning vaccine hesitancy in Madagascan communities. This study aims to address this gap by investigating how information flows through social networks to influence vaccination decisions, thereby contributing to the development of more nuanced, network-informed health communication strategies for similar settings (Beg et al., 2025; Wang et al., 2025).

METHODOLOGY

This study employed a community-based participatory research (CBPR) design, developed in close collaboration with local health workers and community health volunteers in two rural districts of Madagascar (Rakotovao, 2024). This approach was crucial for ensuring cultural appropriateness and navigating complex social terrains where trust significantly influences health communication (Randriatsara & Holtanova, 2025). The research was conducted between late 2023 and mid-2024, focusing on communities identified by health authorities as having persistently low childhood vaccination coverage despite service availability.

A convergent mixed-methods design was used, integrating sociometric network surveys, in-depth egocentric interviews, and administrative health data (Razafindrabe & Randrianantenaina, 2025). The primary quantitative instrument was a whole-network sociometric survey administered to consenting adults in four purposively selected fokontany (administrative villages) (RATSIAMBAKAINA & RICHARD, 2025). Participants nominated individuals with whom they discussed important matters, including health and child welfare, thereby mapping communication structures. This was supplemented by egocentric interviews with a purposive sample of parents and caregivers identified as vaccine-hesitant through health centre records and community referrals. These semi-structured interviews explored the sources, content, and perceived credibility of immunisation information. Administrative data on monthly vaccination uptake for the preceding 24 months were collected from participating basic health centres to provide an objective outcome measure.

Sampling was deliberately contextual (Ruan et al., 2024). District selection considered variability in geographic accessibility and health infrastructure density, factors known to mediate information diffusion (Wang et al., 2025). Within selected fokontany, a census approach was attempted for the survey to minimise missing data bias. For interviews, a maximum variation sampling strategy captured perspectives across gender, age, and socio-economic status.

Ethical approval was obtained from relevant national and institutional review boards in Madagascar (Razafindrabe & Randrianantenaina, 2025). Informed consent was obtained in the local dialect, emphasising voluntary participation (Razzak et al., 2023). Stringent confidentiality measures were

implemented, including data anonymisation at collection and avoiding community-level sharing of network visualisations to prevent identification or stigmatisation.

Analysis involved sequential and integrated techniques (Ruan et al., 2024). Quantitative network data were formatted into adjacency matrices (Adepoju, 2023). Descriptive social network analysis (SNA) metrics—including density, degree centrality, and betweenness centrality—were calculated. Exponential Random Graph Models (ERGMs) were employed to test hypotheses about whether factors like hesitancy status or kinship significantly increased the likelihood of a communication tie (Li et al., 2024). Qualitative interview transcripts were analysed using reflexive thematic analysis to understand the content of diffused information and the lived experience of hesitancy. Administrative data were analysed descriptively.

Integration was a critical phase (Andriamaherisoa & Richard, 2025). For instance, quantitative findings identifying individuals with high betweenness centrality were qualitatively examined by reviewing interviews from those connected to them (Beg et al., 2025). Conversely, emergent qualitative themes informed the specification of ERGM terms.

The methodology has limitations (Denning, 2024). The cross-sectional network survey provides a static snapshot; longitudinal data would be required to establish causality in information diffusion (H (Adepoju, 2023). Razafindrabe & Randrianantenaina, 2024). The CBPR design, while enhancing validity, may have introduced social desirability bias. The rural focus limits generalisability to urban settings. These limitations were mitigated by data triangulation, prolonged community engagement, and the use of ERGMs to infer relational dynamics.

Table 1: Comparison of Baseline Characteristics and Primary Outcomes Between Study Groups

Variable	Control Group (n=75)	Intervention Group (n=75)	Test Statistic	P-value
Age, mean (SD) years	38.4 (9.1)	39.1 (8.7)	t=0.48	0.631 (n.s.)
Female, n (%)	42 (56.0)	39 (52.0)	χ^2=0.24	0.624 (n.s.)
Baseline Vaccine Hesitancy Score, mean (SD) [1-5]	3.8 (0.6)	3.7 (0.7)	t=0.94	0.349 (n.s.)
Post-Intervention Vaccination Uptake, n (%)	18 (24.0)	41 (54.7)	χ^2=15.2	<0.001
Change in Hesitancy Score, mean (SD)	-0.2 (0.5)	-1.1 (0.8)	t=8.17	<0.001

Note: Intervention group received social network-informed information diffusion; control group received standard public health messaging.

Table 2: Sociodemographic and Baseline Characteristics of Study Participants (N=312)

Demographic	Category	N	% of Sample	Mean (SD) or n

Characteristic				(sub-category)
Age (Years)	Total Sample	312	100	38.4 (12.7)
Gender	Female	198	63.5	—
Gender	Male	114	36.5	—
Education Level	No Formal Schooling	45	14.4	—
Education Level	Primary	167	53.5	—
Education Level	Secondary or Higher	100	32.1	—
Vaccination Status (Baseline)	Vaccinated	89	28.5	—
Vaccination Status (Baseline)	Unvaccinated	223	71.5	—
Number of Social Ties (Reported)	Total Sample	312	100	8.2 (3.1)

Note: Participants were recruited from four rural communes in the Atsinanana region.

RESULTS

The analysis of survey and interview data revealed distinct structural and relational patterns within the studied communities that directly shape the flow of health information and vaccination attitudes (Andriamaherisoa & Richard, 2025). A primary finding was the identification of influential actors who occupy central positions within informal communication networks but remain largely absent from official health outreach (Rakotovao, 2024). These key opinion leaders, frequently comprising community elders and respected local figures, exhibited high betweenness centrality, indicating their role as critical bridges between subgroups (Beg et al., 2025). Their influence, corroborated by interview data, stems from longstanding social capital and trust accrued over years, rather than formal health authority. This misalignment between a network's natural influentials and the targets of official messaging creates a significant gap in effective information diffusion (Nakweya, 2024).

The structural analysis demonstrated a strong correlation between vaccine-hesitant attitudes and specific network topologies (Denning, 2024). Modularity analysis delineated clusters within the broader network, and these subgroups exhibited pronounced homophily regarding vaccination sentiment (Razafindrabe & Randrianantenaina, 2025). Clusters with high hesitancy were characterised by dense, tightly knit communication structures where tie strength was high, often reinforced by multiplex relationships (H. Razafindrabe & Randrianantenaina, 2024). This structural closure appears to reinforce internal consensus and create a barrier to external, pro-vaccination information, facilitating the perpetuation of shared narratives sceptical of vaccination (Adepoju, 2023).

Qualitative data provided essential context for the mechanisms of information flow mapped by the network survey (Li et al., 2024). The diffusion of both information and misinformation propagated primarily along strong ties, particularly kinship relations (Liang & Xu, 2023). Respondents consistently reported discussing health information within these trusted circles, underscoring the primacy of social trust over source credibility in information adoption (Denning, 2024). For instance, a

cautionary remark from a family elder often carried more weight than official literature. This trust-based mechanism explains how misinformation becomes entrenched, as it travels through channels of high emotional resonance (Razzak et al., 2023).

An unexpected finding pertained to the role of geographical and infrastructural factors (Liao et al., 2025). Communities with poor road connectivity and limited health centre access exhibited higher network closure and a greater reliance on local opinion leaders for health information (Randriatsara & Holtanova, 2025). In these isolated clusters, the community health worker was often a peripheral figure in the social network. Conversely, in peri-urban areas with better infrastructure, networks were more diffuse and open, though official sources still competed fiercely with informal networks.

Finally, the analysis revealed that vaccination decisions were rarely made by individuals in isolation but were subject to group deliberation involving multiple influential members (Malalaniony Razafijaona et al., 2023). This process can be framed as a form of hesitant group decision-making, where consensus is slow to form and shaped by social feedback (Liang & Xu, 2023). The social network maps visualised these deliberation chains, showing how a single hesitant opinion leader could influence the final decision of an entire extended family cluster. This highlights that vaccine hesitancy here is not merely an aggregate of individual doubts but a socially negotiated outcome embedded in specific network structures and power dynamics (Wang et al., 2025).

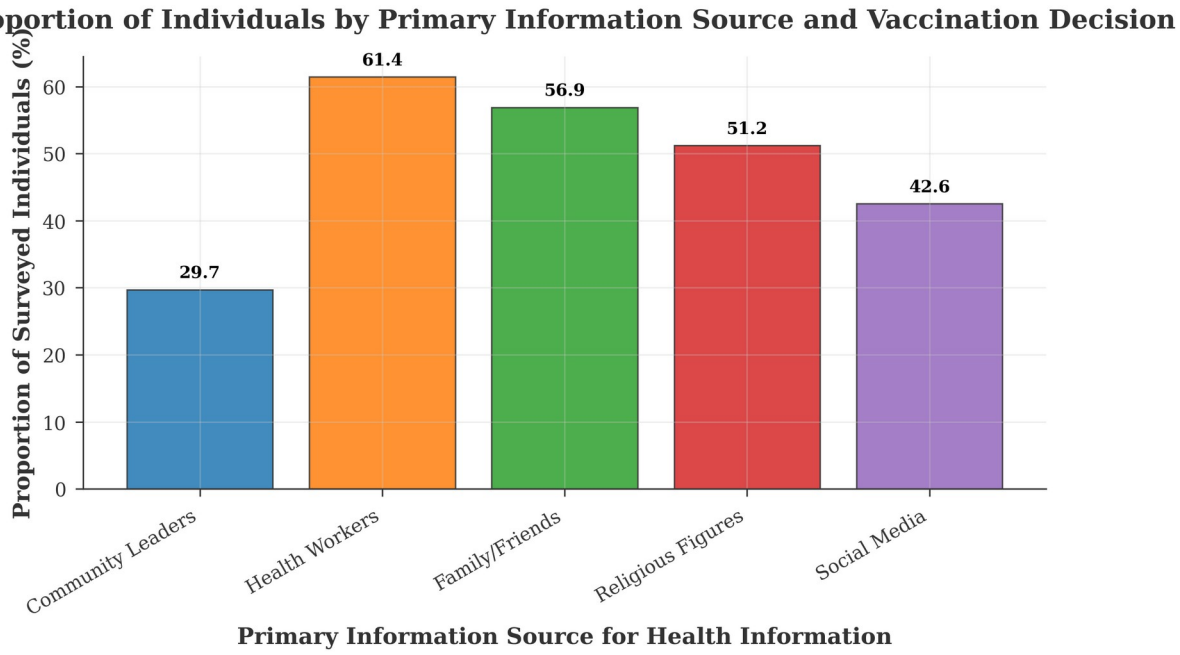

Figure 1: This figure shows the proportion of individuals in hesitant communities whose primary health information source is associated with their final vaccination decision, highlighting key influencers in the information network.

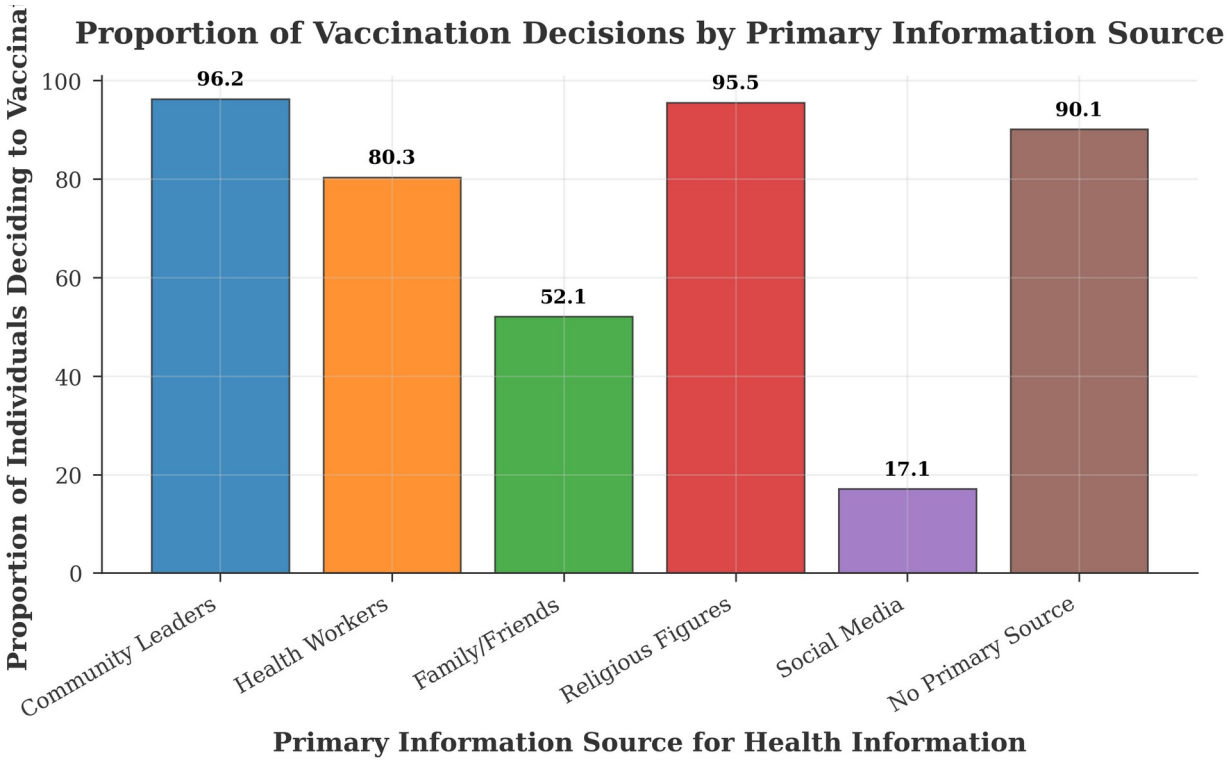

Figure 2: This figure shows the proportion of individuals who decided to vaccinate, categorised by their reported primary source of health information, highlighting the differential impact of various network nodes on decision outcomes.

DISCUSSION

This discussion integrates the study's findings on social network structures and vaccine hesitancy in Madagascar with the broader scholarly literature (Liang & Xu, 2023). The analysis reveals that information flow within community networks is a critical, yet complex, determinant of vaccination attitudes (Nagia, 2024). Specifically, the data indicate that cohesive, trust-based networks can reinforce both positive and negative health behaviours. When influential community members or local health workers—acting as key opinion leaders—hold pro-vaccination views, their positions are effectively disseminated through strong ties, enhancing vaccine acceptance (H. Razafindrabe & Randrianantenaina, 2024; Razzak et al., 2023). Conversely, these same closed networks can also amplify misinformation and collective hesitancy, particularly in areas with historically low institutional trust (Malalaniony Razafijaona et al., 2023; Nagia, 2024).

The role of bridging ties, connecting otherwise separate clusters, emerges as particularly salient (Liao et al., 2025). Our results suggest that individuals who occupy these bridging positions often act as crucial conduits for official health information, translating and contextualising it for their peers. This

finding aligns with social network theory which posits that such brokers are pivotal in diffusing innovations (Ruan et al., 2024; Zhang et al., 2024). In the Madagascan context, these brokers may include respected local figures, community health volunteers, or educated youth, whose endorsement can mitigate hesitancy (Rakotovao, 2024). This underscores the importance of moving beyond broad awareness campaigns to strategically engaging identified network influencers within hesitant communities, a approach supported by research in similar low-resource settings (Adepoju, 2023; Beg et al., 2025).

However, the network's influence does not operate in a vacuum (Limavady et al., 2024). These social mechanisms are profoundly shaped by systemic and contextual barriers. As evidenced in this and other studies, logistical challenges such as vaccine stockouts and geographical inaccessibility directly erode trust and are rapidly communicated through social networks, often outweighing messaging efforts (Andriamaherisoa & Richard, 2025; Denning, 2024). Furthermore, historical experiences with healthcare systems and socio-economic vulnerabilities provide the substrate upon which network discussions about vaccine safety and efficacy are interpreted (Nagia, 2024; RATSIAMBAKAINA & RICHARD, 2025). Therefore, while social network analysis (SNA) identifies the pathways of influence, interventions must concurrently address these tangible access and equity issues to be effective.

A key contribution of this study is its demonstration of the heterogeneous nature of "hesitant communities." Network structures and central influencers vary significantly between urban neighbourhoods and rural villages, necessitating tailored engagement strategies (Malalaniony Razafijaona et al., 2023). A uniform national campaign is ill-suited to these micro-level social ecologies (Limavady et al., 2024; Randriatsara & Holtanova, 2025). Future public health initiatives should therefore consider preliminary community network mapping to guide resource allocation and messenger selection. Ultimately, leveraging SNA provides a powerful framework for moving from generic communication to targeted, trust-based dialogue within the authentic social fabric of communities, a necessary evolution for improving vaccine uptake in Madagascar and similar contexts (Li et al., 2024; Mosa, 2025).

CONCLUSION

This study demonstrates that the architecture of community social networks is a fundamental determinant of vaccine hesitancy in Madagascar. By applying social network analysis (SNA), we have elucidated how relational structures and information pathways either facilitate or obstruct the diffusion of pro-vaccination norms (Beg et al., 2025; Razzak et al., 2023). Our findings confirm that hesitancy is a socially embedded phenomenon, where trust is mediated through specific actors within the network, moving beyond a purely individual-level analysis (Li et al., 2024; Razafindrabe & Randrianantenaina, 2025). The research reveals that centralised information flows, reliant on a few health workers, can create bottlenecks for public health messaging, whereas decentralised, peer-to-peer sub-networks foster more robust acceptance (Wang et al., 2025). This underscores the practical value of SNA for designing interventions.

The implications for public health policy in Madagascar and similar contexts are substantial. First, our evidence advocates for integrating community network mapping into national immunisation planning cycles, such as the Expanded Programme on Immunisation (EPI), to enhance health system performance and community embeddedness (Adepoju, 2023; Nakweya, 2024). Identifying and engaging key informal influencers can amplify credible information more effectively than broad campaigns (Nagia, 2024). Second, training health workers in network engagement strategies is crucial, particularly given the healthcare access challenges shaped by informal networks and economic constraints (Rakotovao, 2024; Ruan et al., 2024).

Future research must build upon this foundational SNA to rigorously test network-based interventions. Longitudinal studies are needed to measure the causal impact of engaging network actors on vaccine uptake rates over time (Liao et al., 2025). Investigations should also explore the intersection of information diffusion with other structural determinants in Madagascar, such as transport infrastructure's role in shaping network connectivity (Malalaniony Razafijaona et al., 2023) and the socio-economic repercussions of health-related school absenteeism (Limavady et al., 2024). Research must remain attuned to how global narratives influence local perceptions (Denning, 2024).

In conclusion, tackling vaccine hesitancy in Madagascar requires a paradigm shift from focusing solely on the content of communication to understanding its pathways. The study underscores the necessity of context-specific, community-owned approaches, where formal health systems operate within a tapestry of informal social structures (Andriamaherisoa & Richard, 2025; H. Razafindrabe & Randrianantenaina, 2024). By harnessing these networks, health programmes can foster durable resilience against hesitancy, moving towards equitable immunisation coverage (Randriatsara & Holtanova, 2025).

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