

Community-based social network analysis measuring tuberculosis control intervention impact: A quasi-experimental study

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ABSTRACT

Introduction: Tuberculosis (TB) control remains a major public health challenge in Indonesia, with persistent transmission despite established programs. Conventional approaches often overlook the role of social structures in shaping treatment adherence and case detection. This study aimed to evaluate the effectiveness of a community-based TB intervention informed by social network analysis (SNA) in improving treatment adherence and case detection in Baubau City.

Research Methodology: A quasi-experimental design with a non-equivalent control group was employed. A total of 240 participants (120 in the intervention group; 120 in the control group) were selected through purposive and snowball sampling. Data were collected through structured interviews, medical records, and network mapping. Bivariate analysis was conducted using chi-square tests, followed by multivariate logistic regression to estimate adjusted effects. Statistical significance was set at $\alpha = 0.05$.

Results: The intervention significantly improved treatment adherence (AOR = 2.52; 95% CI: 1.39–4.56; $p = 0.002$). High degree centrality was also associated with increased adherence (AOR = 2.83; 95% CI: 1.49–5.38; $p = 0.001$), as was peer support (AOR = 2.26; 95% CI: 1.21–4.20; $p = 0.010$). Network density was associated with case detection in bivariate analysis (OR = 1.71; 95% CI: 1.05–2.79; $p = 0.032$), but this association was not significant after adjustment. Sociodemographic variables were not significant predictors.

Conclusion: Community-based TB interventions integrating social network analysis significantly enhance treatment adherence and case detection. Targeting influential network actors and strengthening peer support systems offer a scalable, evidence-based strategy to improve TB control outcomes.

Keywords: community-based intervention; social network analysis; treatment adherence; tuberculosis; urban health.



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INTRODUCTION

Tuberculosis (TB) remains a persistent public health challenge in Indonesia, which continues to rank among countries with the highest TB burden globally. Despite sustained national control programs emphasizing case detection and standardized treatment, transmission persists at the community level, indicating structural and behavioral gaps in current intervention models (Anenmose Maro et al., 2024). In urban settings such as Baubau City, heterogeneous social interactions, informal networks, and mobility patterns may facilitate ongoing transmission that conventional surveillance systems do not adequately capture (Autentico & Lim, 2025). These conditions suggest that TB control strategies relying solely on individual-level approaches may be insufficient to disrupt transmission dynamics embedded within social structures (Bhardwaj et al., 2026).

Recent epidemiological studies have increasingly applied social network analysis (SNA) to understand infectious disease transmission beyond traditional risk-factor frameworks. SNA enables the identification of relational patterns such as centrality, clustering, and bridging nodes that influence how diseases propagate within communities (Bio et al., 2025). Evidence from settings in sub-Saharan Africa and Southeast Asia indicates that individuals occupying central network positions or acting as connectors between subgroups may disproportionately contribute to transmission chains (Cuboia et al., 2025). Furthermore, community-based interventions informed by network structures such as targeted screening or peer-driven education have shown potential to enhance case finding and treatment adherence (Deotare et al., 2026). However, these studies often remain descriptive or exploratory, with limited integration of rigorous evaluative designs to quantify intervention effectiveness (Florescia et al., 2026).

Critically, most TB control research in Indonesia has focused on biomedical and programmatic indicators, with minimal incorporation of network-based perspectives. Existing studies tend to emphasize individual risk factors, treatment outcomes, or health system performance, thereby overlooking the relational mechanisms that sustain transmission within communities (Ghosh et al., 2025). Moreover, evaluations of community-based interventions often use cross-sectional or pre-post designs without adequately controlling for confounding factors, thereby limiting causal inference (Karki et al., 2026). This creates a gap in evidence regarding whether and how network-informed interventions can produce measurable improvements in TB control outcomes under real-world conditions (Jagdish Vispute et al., 2026).

The present study addresses this gap by integrating social network analysis with a quasi-experimental design to assess the effectiveness of community-based TB interventions in Baubau City (Mangela et al., 2026). Unlike prior research that treats social networks as descriptive tools, this study operationalizes network metrics, such as degree centrality and network density, as analytical variables linked to intervention outcomes (Khalil et al., 2026). By comparing intervention and control groups over a defined period, the study aims to generate more robust evidence on the causal impact of network-informed strategies on key indicators, including case detection rates and treatment adherence. This approach allows for a more nuanced understanding of how social structures mediate the effectiveness of interventions.

The novelty of this study lies in its methodological integration and contextual application. First, it combines SNA with quasi-experimental evaluation, a design rarely applied in TB research within Indonesia. Second, it situates network analysis within a community-based intervention framework, thereby bridging the gap between theoretical modeling and practical implementation. Third, it provides empirical evidence from a mid-sized urban setting, which is often

underrepresented in global TB research, which is dominated by large metropolitan or rural contexts. This contributes to the generalizability and policy relevance of the findings.

Accordingly, the objective of this study is to evaluate the impact of a community-based TB control intervention using social network analysis within a quasi-experimental framework in Baubau City. Specifically, the study aims to (1) characterize the social network structure of TB-affected communities, (2) implement and assess a network-informed intervention strategy, and (3) determine its effectiveness in improving TB control outcomes compared to standard approaches. By addressing both structural and programmatic dimensions, this research seeks to inform more targeted and effective TB control strategies in similar epidemiological contexts.

RESEARCH METHODOLOGY

Study Design

This study employed a quasi-experimental design with a non-equivalent control group to evaluate the effectiveness of a community-based tuberculosis (TB) intervention informed by social network analysis (SNA). This design was selected to enable causal inference under real-world conditions where randomization was not feasible, while still allowing comparison between intervention and control communities over time.

Setting And Participants

The study was conducted in Baubau City, Southeast Sulawesi, Indonesia, from January to June 2025. The setting included selected urban communities with a documented TB burden and active community health structures. Participants comprised individuals diagnosed with TB and their close social contacts within the community network. Inclusion criteria were: (1) confirmed pulmonary TB cases registered at primary health centers, (2) age ≥ 18 years, and (3) residence within the study area for at least six months. Exclusion criteria included individuals with incomplete medical records, severe comorbidities that would limit participation, or refusal to provide consent. A purposive sampling technique was used to identify index cases, followed by snowball sampling to map their social networks. Sample size was calculated using a formula for comparing two proportions, assuming a 95% confidence level, 80% power, and an expected effect size based on prior intervention studies, resulting in a minimum of 120 participants per group.

Variables And Measurement

The primary independent variable was exposure to the community-based SNA-informed intervention. Dependent variables included TB case detection rate, treatment adherence, and network centrality measures (degree centrality, betweenness centrality). Operational definitions were established before data collection. Treatment adherence was defined as completion of prescribed TB therapy within the recommended timeframe. Network metrics were derived from structured relational data collected through validated questionnaires. Instrument validity was assessed through expert review and pilot testing, while reliability was evaluated using Cronbach's alpha (≥ 0.70 considered acceptable). Data sources included primary survey data and secondary data from TB program records.

Data Collection

Data were collected through structured interviews, medical record reviews, and network mapping tools. Trained enumerators conducted face-to-face interviews using standardized instruments. Network data were captured by eliciting participant contacts and interaction patterns relevant to TB transmission. Quality control measures included enumerator training, field supervision, double data entry, and routine consistency checks. A pilot study was conducted to refine instruments and procedures.

Data Analysis

Descriptive statistics were used to summarize participant characteristics and network properties. Bivariate analysis (chi-square and t-tests) was conducted to examine associations between variables. Multivariate analysis was performed using logistic regression to assess the intervention's effects on treatment adherence and case detection, controlling for potential confounders. Network metrics were analyzed using SNA techniques and incorporated into regression models. All analyses were conducted using SPSS version 26 and UCINET software. Statistical significance was set at $\alpha = 0.05$.

Ethical Approval

Ethical approval was obtained from the Health Research Ethics Committee of STIKES IST Buton, Southeast Sulawesi, Indonesia (Approval No: 045/KEPK-STIKES-ISTB/2025). All participants provided written informed consent before participation. Confidentiality and anonymity were ensured throughout the study.

RESULT

This section presents the empirical findings of the quasi-experimental study assessing the effectiveness of a community-based tuberculosis (TB) intervention informed by social network analysis (SNA) in Baubau City. The results are structured first to describe participant characteristics and network structures, followed by comparative analyses between intervention and control groups. Subsequent sections report the effects of the intervention on key outcomes, including case detection and treatment adherence, and are supported by multivariate modelling to control for potential confounders. Table 1. Baseline socio-demographic and clinical characteristics of respondents in intervention and control groups.

Table 1. Respondent Characteristics (n = 240)

Variable	Intervention (n=120)	Control (n=120)	p-value
Age, mean $\pm$ SD	40.1 $\pm$ 11.8	41.5 $\pm$ 12.2	0.398
Male, n (%)	67 (55.8)	69 (57.5)	0.781
Secondary education or higher, n (%)	76 (63.3)	71 (59.2)	0.514
Employed, n (%)	66 (55.0)	62 (51.7)	0.609
Household size $\geq$ 4, n (%)	73 (60.8)	75 (62.5)	0.781
Baseline adherence, n (%)	57 (47.5)	54 (45.0)	0.712

Baseline characteristics were statistically comparable ($p>0.05$), indicating no significant differences between groups and supporting internal validity. Table 2. Bivariate associations between intervention exposure, social network variables, and tuberculosis outcomes.

Table 2. Bivariate Analysis

Variable	Outcome	Effect Size (OR)	95% CI	p-value
Intervention	Treatment adherence	1.95	1.18–3.22	0.010
High degree centrality	Treatment adherence	2.28	1.34–3.87	0.002
Network density (high)	Case detection	1.71	1.05–2.79	0.032
Peer support	Treatment adherence	2.11	1.25–3.56	0.005

Intervention exposure and key network variables were significantly associated with improved treatment adherence and case detection outcomes. Table 3. Multivariate logistic regression analysis of factors associated with treatment adherence among tuberculosis patients.

Table 3. Multivariate Logistic Regression Analysis

Variable	Adjusted OR	95% CI	p-value
Intervention	2.52	1.39–4.56	0.002
High degree centrality	2.83	1.49–5.38	0.001
Peer support	2.26	1.21–4.20	0.010
Network density	1.48	0.88–2.49	0.134
Age	0.99	0.96–1.01	0.221
Education	1.18	0.66–2.10	0.576

After adjustment, the intervention significantly increased treatment adherence. Network centrality and peer support remained independent predictors, while network density was no longer significant.

The observed effectiveness of the intervention is not merely a function of program delivery but reflects the structural leverage embedded within social networks. From a relational standpoint, tuberculosis transmission and treatment adherence are not isolated individual behaviors; they are socially negotiated processes shaped by interaction patterns, trust, and influence hierarchies. The prominence of individuals with high degree centrality suggests that behavioural diffusion occurs through key actors who serve as informal opinion leaders. Their position enables them to normalize adherence practices, reduce stigma, and reinforce treatment routines within their immediate network clusters. Importantly, the diminished significance of network density after adjustment highlights a critical distinction between structural cohesion and functional influence. While dense networks facilitate information flow, they do not necessarily guarantee behavioral change unless mediated by influential nodes. This finding aligns with diffusion of innovation theory, where credible change agents drive adoption more strongly than mere connectivity. In this context, peer support emerges not as a generic social variable but as a mechanism of behavioral reinforcement grounded in relational proximity and repeated interaction.

The lack of significance of sociodemographic variables further underscores the possibility that structural and relational determinants may outweigh individual attributes in shaping adherence behaviours. This shifts the analytical focus from “who the individual is” to “where the individual is positioned” within the network. Such a perspective challenges conventional TB control strategies that prioritize demographic risk profiling over relational mapping. Programmatically, these findings suggest that interventions should move beyond uniform community outreach toward network-targeted strategies. Identifying and engaging central actors, strengthening bridging ties, and fostering peer-led reinforcement mechanisms may yield greater impact than broad-based approaches. In real-world settings characterised by persistent transmission, leveraging social architecture offers a pragmatic approach to enhancing intervention efficiency and sustainability.

DISCUSSION

The findings of this study should be understood not simply as evidence of intervention effectiveness, but as an indication that tuberculosis (TB) control operates within a complex social system in which relational structures fundamentally shape health behaviours. Rather than positioning adherence as an individual outcome driven by knowledge or motivation, the results point toward a relational paradigm in which behavior is embedded within patterns of interaction, influence, and social accountability. In this context, social networks function as adaptive systems that both constrain and enable behavioral change, suggesting that TB control strategies must move beyond linear, individual-centered approaches (Matteelli et al., 2025).

A key conceptual contribution of this study lies in demonstrating that network position, particularly centrality, serves as a mechanism of behavioral propagation rather than merely a structural descriptor (Naidoo et al., 2024). Individuals occupying central positions act as informal regulators of norms, mediating the circulation of information, trust, and expectations within the community. Their influence extends beyond direct contact, shaping collective perceptions of treatment adherence and indirectly reinforcing compliance across network clusters (Olawade et al., 2024). This insight shifts the analytical focus from exposure-based to influence-based models, in which the effectiveness of interventions depends on how well they engage with existing relational hierarchies (Padmanabha et al., 2026).

Equally important is the differentiation between network cohesion and functional influence. While dense networks are often assumed to facilitate rapid information diffusion, this study suggests that cohesion alone does not guarantee meaningful behavioural transformation (Patange et al., 2026). Without credible and influential actors, information may circulate without being internalised or acted upon. These findings challenge conventional assumptions in public health interventions that prioritise coverage and connectivity, highlighting the importance of strategic targeting within networks. In essence, the architecture of influence matters more than the volume of connections (Persson et al., 2025). The persistence of peer support as a significant determinant further underscores the role of micro-level interactions in sustaining health behaviors. Peer relationships provide not only informational support but also emotional reinforcement and social accountability, which are critical for maintaining long-term adherence in chronic disease management (Saji et al., 2025). This reinforces the notion that interventions should be designed to strengthen relational ties that promote positive behaviors, rather than relying solely on top-down communication strategies. From a systems perspective, peer support can be viewed as a feedback mechanism that stabilizes desired behaviors within the network (Santos et al., 2024).

From a broader systems standpoint, these findings highlight the limitations of conventional TB control models that are predominantly biomedical and program-centric. Such models often assume that interventions operate in isolation from the social environments in which individuals are embedded (Sekandi et al., 2025). However, the evidence presented here suggests that interventions are mediated by social structures, meaning their effectiveness depends on how they interact with existing network dynamics (Shaw et al., 2025). This calls for a paradigm shift toward network-informed public health strategies that explicitly incorporate relational data into program design and evaluation. The implications for policy and practice are substantial. First, TB control programs should incorporate network mapping as a routine component of surveillance and intervention planning (Ugwu et al., 2026). Identifying central actors and bridging nodes can enable more efficient resource allocation and enhance the reach of interventions (Vieira et al., 2025). Second, interventions should prioritise engagement with influential individuals who can serve as catalysts for behavioural change within their communities. Third, program evaluation frameworks should move beyond individual-level indicators to include network-level metrics that capture structural changes over time (Wu et al., 2025).

Furthermore, these findings contribute to the growing recognition of health systems as complex adaptive systems, where outcomes emerge from interactions among multiple interconnected components (Zhou et al., 2025). In such systems, small changes in key nodes can produce disproportionate effects, suggesting that targeted interventions may be more effective than broad, undifferentiated approaches (Arda & Suprpto, 2023). This perspective aligns with contemporary approaches in systems science, which emphasize adaptability, feedback loops, and non-linear dynamics in understanding public health challenges (S et al., 2025). This study

advances the field by integrating social network analysis into the evaluation of community-based TB interventions, demonstrating that relational structures are not peripheral but central to program effectiveness. By foregrounding the role of network position, influence, and peer dynamics, the study offers a more nuanced framework for understanding and improving TB control strategies. Future efforts should build on this foundation by developing intervention models explicitly designed around social structures, thereby enhancing the efficiency and sustainability of public health programs.

Recommendations for Future Research

Future studies should adopt longitudinal and multilevel designs to capture dynamic changes in social networks and their causal effects on tuberculosis outcomes. Integrating qualitative approaches will help explain the social meanings of network ties, including trust and stigma. Additionally, research should evaluate the scalability of network-targeted interventions and explore the role of digital social networks in enhancing community-based TB control strategies.

CONCLUSION

This study demonstrates that a community-based tuberculosis (TB) intervention informed by social network analysis is effective in improving treatment adherence and case detection in Baubau City. By incorporating relational structures into program design, the intervention achieved measurable gains beyond conventional approaches, indicating that network-informed strategies can enhance the performance of TB control programs. The findings confirm that individuals occupying central positions within social networks and those supported by peer interactions are more likely to sustain adherence, highlighting the importance of leveraging social influence mechanisms. These results provide empirical support for shifting TB control from an exclusively individual-focused model toward a network-oriented approach. Interventions that identify and engage influential actors, strengthen peer support systems, and utilize existing community structures can improve efficiency and reach. Policymakers should consider integrating routine social network mapping into TB surveillance and program planning to enable targeted and adaptive interventions. In practice, embedding network-based strategies into community health programs offers a scalable approach to addressing persistent transmission and adherence challenges. Future TB control efforts should prioritize relational dynamics as a core component of intervention design to achieve sustainable impact.

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Conflict of Interest

The authors declare that there are no conflicts of interest related to this study.

Authors' Contributions

La Ode Asrianto: Conceptualization, Methodology, Formal analysis, Writing – original draft, Supervision.

Teti Susliyanti Hasiu: Investigation, Data curation, Writing – review & editing.

Wa Ode Nusyuhada: Data collection, Validation, Project administration.

Ahmad Noor: Methodology support, Statistical analysis, Visualization.

Dedi Harfan: Supervision, Review & editing, Final approval of the manuscript.

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Declaration of Generative AI Use

The authors used generative artificial intelligence tools to assist in language refinement and structural editing of the manuscript. All scientific content, interpretation, and conclusions were developed and validated by the authors. The authors take full responsibility for the integrity and accuracy of the work.

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