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A Bayesian Hierarchical Model for Longitudinal Risk Reduction in Tanzanian Community Health Centre Systems

A Methodological Evaluation, 2000–2026

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ABSTRACT

Background: Longitudinal assessments of public health interventions in resource-limited settings are hindered by complex, multi-level data structures and non-random missingness. Existing analytical approaches often fail to adequately account for temporal dependencies and heterogeneity across community health centres, limiting robust inference on intervention efficacy.

Purpose and objectives: This study aimed to develop and methodologically evaluate a Bayesian hierarchical model designed to estimate longitudinal risk reduction within decentralised community health systems. The objective was to provide a robust framework for quantifying intervention effects over time while handling inherent data complexities.

Methodology: We conducted a longitudinal methodological evaluation using data from a national community health programme. The core model is specified as $y\{it\} \sim \text{Bernoulli}(\text{logit}^{-1}(\alpha\{i\} + \beta t + \gamma z\{it\}))$, with $\alpha\{i\} \sim \text{Normal}(\mu\{\alpha\}, \sigma^2\{\alpha\})$, where $y\{it\}$ is the binary outcome for centre i at time t, $\alpha\{i\}$ are centre-specific random intercepts, and $z\{it\}$ represents time-varying intervention exposure. Model performance was evaluated using posterior predictive checks and comparisons to frequentist alternatives.

Keywords: *Bayesian hierarchical modelling, longitudinal data analysis, community health systems, Sub-Saharan Africa, risk reduction, methodological evaluation, missing data*

Article Highlights

- Superior handling of missing data and centre-level heterogeneity compared to frequentist methods
- Identified significant variation in baseline risk across community health centres
- Provides rigorous uncertainty quantification for complex longitudinal evaluations

Core Model Specification

y_it ~ Bernoulli(logit⁻¹(α_i + βt + γz_it)), with α_i ~ Normal(μ_α, σ²_α), where y_it is the binary outcome for centre i at time t, α_i are centre-specific random intercepts, and z_it represents time-varying intervention exposure.

This methodological evaluation focuses on statistical framework development rather than clinical outcomes.

ABSTRACT-ONLY PUBLICATION

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