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Data-Linked Community-Health Facility Strategy to Identify and Reach Zero-Dose Children in Urban Informal Settlements: An Implementation Study in Wakiso District, Uganda

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Abstract

Despite substantial global progress in routine childhood immunisation, inequities persist, particularly among children living in urban informal settlements. Globally, an estimated 13 million children remain zero-dose each year—defined as children who have not received the first dose of a diphtheria–tetanus–pertussis (DTP)-containing vaccine. These children represent the most systematically excluded populations within immunisation systems and face the highest risk of vaccine-preventable diseases. In Uganda, rapid urbanisation has contributed to the concentration of zero-dose children in peri-urban districts such as Wakiso, where informal settlements are characterised by high population mobility, weak community–health facility linkages, and fragmented immunisation data systems. This study evaluates the effectiveness and implementation performance of a data-linked community–health facility strategy to improve identification, referral completion, and vaccination uptake among zero-dose and under-immunised children aged 0–23 months in urban informal settlements of Wakiso District, Uganda. A mixed-methods implementation research design will be used. Quantitative data will be obtained from routine immunisation records, household verification surveys, and integrated community registers, while qualitative data will be collected through focus group discussions and key informant interviews with caregivers, Village Health Teams, and health workers. Primary outcomes include changes in the identification and vaccination initiation of zero-dose children, measured through DTP1 uptake. Secondary outcomes include the acceptability, feasibility, and scalability of the intervention using the RE-AIM (Reach, Effectiveness, Adoption, Implementation and Maintenance) framework. By strengthening integration between community-generated data and health facility immunisation records, the study aims to generate practical implementation evidence for improving immunisation equity in urban informal settlements. Findings will inform district immunisation microplanning and outreach strategies. The study will also generate implementation-relevant evidence to support national immunisation policy and scalable approaches for identifying and reaching zero-dose children in rapidly urbanising settings.

Keywords: *Immunization Equity, Implementation Research, Routine Immunization, Uganda, Urban Informal Settlements, Zero-Dose Children.*

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Introduction

Routine childhood immunisation remains one of the most effective public health interventions for reducing morbidity and mortality from vaccine-preventable diseases. Over the past two decades, global immunisation programmes have significantly expanded coverage, contributing to major declines in childhood mortality [1]. However, these gains have not been equitably distributed. An estimated 13 million children globally remain zero-dose each year, meaning they have not received the first dose of a diphtheria–tetanus–pertussis containing vaccine (DTP1), which serves as a key tracer indicator for immunisation system reach [2].

Zero-dose children represent populations that are systematically excluded from routine health services and are often concentrated among the poorest and most marginalised communities [3]. Recent global evidence indicates that the epidemiology of zero-dose children is shifting from predominantly rural settings to rapidly growing urban areas, particularly informal settlements in low- and middle-income countries [4]. These communities often experience overcrowding, insecure housing, high population mobility, and limited access to basic services, which collectively undermine routine immunisation delivery [5].

The phenomenon known as the "urban proximity paradox" highlights that children living near health facilities in informal settlements are sometimes less likely to receive vaccines than those living in rural areas [6]. Structural barriers, fragmented data systems, and weak community–facility linkages contribute to missed opportunities for vaccination despite geographic proximity to health services.

Uganda reflects similar trends. Although national routine immunisation coverage has improved over time, inequities persist, particularly in rapidly urbanising districts surrounding Kampala [7]. Wakiso District—the most populous district in Uganda—reports some of the highest absolute numbers of zero-dose children nationally. The district contains numerous urban informal settlements characterised by high population turnover and complex health service delivery challenges.

Routine immunisation data systems in Uganda include the District Health Information System 2 (DHIS2), the electronic Community Health Information System (eCHIS), health facility immunisation registers, and Village Health Team (VHT) household registers. However, these systems frequently operate in parallel rather than as an integrated ecosystem, limiting the ability of health workers to accurately identify and follow up missed children [8].

Evidence from other urban African settings suggests that integrating community-level data with health facility immunisation records, combined with community health worker follow-up and flexible service delivery models, can substantially reduce the burden of zero-dose children [9]. Nevertheless, empirical evidence on how such data-linked community–facility strategies can be operationalised within Uganda's routine health system remains limited.

Structural barriers, vaccine hesitancy, and social determinants of health have also been identified as important contributors to missed vaccinations in urban and low-resource settings [11–16].

The conceptual framework guiding this study integrates Andersen's Behavioural Model of Health Service Use, the Socio-Ecological Model (SEM), and the RE-AIM implementation framework to explain the determinants of zero-dose status and the mechanisms through which the intervention is expected to improve immunisation outcomes [17–19].

At the input level, predisposing and enabling factors—including caregiver knowledge, beliefs, past experiences with health services, access to vaccination services, and associated

costs—interact with broader socio-ecological influences operating at individual, interpersonal, community, and health system levels. These interacting factors contribute to the persistence of zero-dose and under-immunised children in urban informal settlements.

The intervention focuses on strengthening a data-linked community–health facility strategy, whereby immunisation data from DHIS2, health facility registers, and Village Health Team (VHT) household records are systematically triangulated to improve identification, referral, and follow-up of zero-dose and under-immunised children. Key implementation mechanisms include DHIS2-guided targeting, VHT-led household mapping and follow-up, mobile and flexible outreach services, and participatory co-design with communities to improve service accessibility and responsiveness to the realities of urban informal settlements.

Implementation performance and outcomes are evaluated using the RE-AIM framework, which assesses the intervention's reach, effectiveness, adoption, implementation fidelity, and maintenance within routine district health systems [19]. Through these mechanisms, the intervention is expected to contribute to increased vaccination coverage, reduced prevalence of zero-dose children, and strengthened immunisation planning capacity at the district level.

Ultimately, the framework illustrates how addressing behavioural, structural, and health system determinants through data-linked community–facility collaboration can improve identification and vaccination of missed children, thereby contributing to improved immunisation equity in urban informal settlements. The relationships between these determinants and the intervention mechanisms are illustrated in Figure 1.

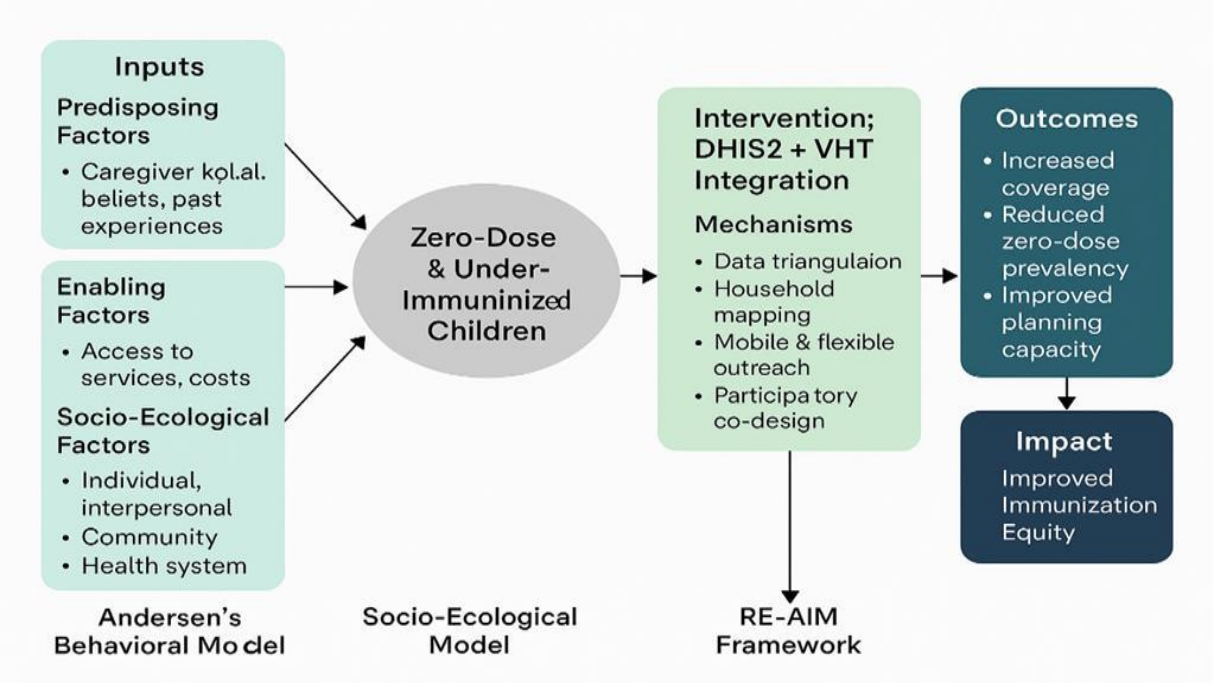

Figure 1. Conceptual Framework Illustrating the Determinants of Zero-Dose Children and the Data-Linked Community–Health Facility Intervention Integrating Andersen's Behavioral Model, the Socio-Ecological Model, and the RE-AIM Implementation Framework. Developed by the Author based on Established Theoretical Models [17–19]

This study therefore aims to assess the effectiveness and implementation performance of a data-linked community–health facility strategy to improve identification, referral completion, and vaccination uptake among zero-dose children living in urban informal settlements of Wakiso District.

Materials and Methods

Study Design

This study employs a mixed-methods implementation research design to evaluate the effectiveness and operational feasibility of a data-linked community–health facility strategy for identifying, referring, and vaccinating zero-dose children in urban informal settlements of Wakiso District, Uganda.

The study integrates quantitative and qualitative approaches to assess both intervention outcomes and implementation processes under real-world service delivery conditions. Quantitatively, the study measures changes in the identification, referral completion, and vaccination uptake of zero-dose children, while qualitatively exploring behavioural, contextual, and health system factors that influence implementation of the strategy.

The methodological approach combines cross-sectional prevalence assessment, analytical household survey, and prospective implementation evaluation within a single integrated study framework. Routine immunisation data sources—including DHIS2 reports, health facility immunisation registers, the electronic Community Health Information System (eCHIS), and Village Health Team (VHT) household registers—will be triangulated with household verification and geospatial mapping to identify and track zero-dose and under-immunised children.

In addition, focus group discussions (FGDs) with caregivers and key informant interviews (KIIs) with health workers, VHTs, and district immunisation managers will be conducted to explore perceptions of feasibility, acceptability, and scalability of the intervention. The implementation process and outcomes will be evaluated using the RE-AIM framework, which assesses reach, effectiveness, adoption, implementation fidelity, and maintenance within routine health system settings.

This mixed-methods design enables a comprehensive assessment of both the effectiveness of the intervention and the contextual factors influencing its implementation, thereby generating implementation-relevant evidence to inform strategies for reducing immunisation inequities in urban informal settlements.

Study Setting

The study will be conducted in selected urban informal settlements in Wakiso District, Uganda, which forms part of the Greater Kampala Metropolitan Area (GKMA). Wakiso District is the most populous district in Uganda and has experienced rapid urbanisation characterised by expanding informal settlements, high population density, and significant population mobility [20, 21]. These structural and demographic dynamics contribute to persistent inequities in access to routine childhood immunisation services.

The selected study sites include urban informal settlements served by lower-level public health facilities providing routine immunisation services under the Uganda National Expanded Programme on Immunization (UNEPI). These facilities include Health Centre II, Health Centre III, and Health Centre IV levels, which provide both facility-based and outreach vaccination services to densely populated communities [22].

Routine immunisation programme reports indicate that urban informal settlements in Wakiso District represent high-burden areas for zero-dose and under-immunised children, partly due to fragmented immunisation data systems, high population mobility, and weak community–health facility linkage mechanisms [23, 24]. These characteristics make Wakiso

District an appropriate setting for evaluating a data-linked community–health facility strategy aimed at improving identification, referral, and vaccination uptake among missed children.

To ensure that the study will be implemented in high-burden settings, four urban informal settlements were purposively identified based on analysis of routine immunisation data from the District Health Information System 2 (DHIS2). In collaboration with district immunisation programme managers and following Ministry of Health guidance for identification of priority areas for zero-dose interventions, DHIS2 indicators including DTP1 coverage, dropout rates, and reported numbers of zero-dose children were reviewed. Settlements consistently reporting high numbers of missed or under-immunised children were identified and selected as the primary implementation sites for the study.

Study Population

The study population will comprise children aged 0–23 months living in selected urban informal settlements of Wakiso District, Uganda, and the individuals involved in their immunisation care and service delivery. Specifically, the study will include caregivers of children aged 0–23 months, who are responsible for making decisions regarding child health and vaccination.

In addition, the study will involve Village Health Team (VHT) members, who serve as community-based health volunteers responsible for household registration, health education, and referral of children for immunisation services. Health workers involved in routine immunisation service delivery at selected health facilities will also participate, including those responsible for vaccination services, child registers, and outreach activities.

Furthermore, district and sub-district immunisation programme managers, including Expanded Programme on Immunization (EPI) focal persons, will be included as key informants to provide insights on programme implementation, supervision, and health system factors influencing the identification and follow-up of zero-dose children.

Sample Size

The sample size for the household survey was estimated using the single population proportion formula**:**

$$n = \frac{Z^2 p(1-p)}{d^2}$$

- n = required sample size.
- Z = Z-score for 95% confidence level (1.96).
- p = estimated prevalence of zero-dose children.
- d = margin of error (0.05).

Assuming a zero-dose prevalence of 12%**,** a 95% confidence level**,** and 5% margin of error, the minimum sample size was estimated at approximately 162 children**.**

To account for non-response and population mobility, a 10% adjustment will be applied:

$$n\_adj = \frac{\text{n}}{1-\%\, non-response}.$$

n_adj = 162 / 0.9 = 180.

Given that sampling will occur within clustered settlement environments, a design effect (DEFF) of 1.5 will be applied to adjust for potential intra-cluster correlation:

$$n\_final = nadj\ x\ DEFF.$$

n_final = 180 × 1.5 = 270.

Therefore, the statistically derived minimum sample size for the quantitative component of the study is 270 caregiver–child pairs.

However, to enhance statistical power, allow for subgroup analyses across different informal settlements, and mitigate operational challenges such as high population mobility and incomplete household records, the study will target approximately 500 caregiver–child pairs.

Data Collection

Quantitative Data

Quantitative data will be collected using multiple complementary sources to support identification and verification of zero-dose and

under-immunised children. These will include structured household caregiver surveys, review of health facility immunisation registers, and Village Health Team (VHT) household child registers. Additional data will be obtained from routine health information systems, including the electronic Community Health Information System (eCHIS) and the District Health Information System 2 (DHIS2). Household visits will also involve GPS-enabled verification of households to confirm residence and support geospatial mapping of zero-dose and under-immunised children within the study settlements.

In order to identify zero-dose and under-immunised children who may not appear in routine health facility or community registers, the study will incorporate active household verification within the selected settlements. Village Health Teams (VHTs) will support household mapping and listing of children aged 0–23 months within their catchment areas. Trained research assistants will then conduct structured household caregiver surveys to verify vaccination status using child health cards where available, or caregiver recall when documentation is not available. Children identified during household visits who have not received any routine vaccines, including the first dose of a diphtheria–tetanus–pertussis containing vaccine (DTP1), will be classified as zero-dose children, while those who have initiated but not completed the recommended schedule will be classified as under-immunised. Information obtained from household verification will be cross-checked with health facility immunisation registers, Village Health Team household registers, and electronic health information systems such as eCHIS to validate vaccination status and support referral and follow-up of missed children. This approach enables the study to identify both registered and previously unregistered children, thereby improving the completeness and accuracy of zero-dose identification in urban informal settlements.

Qualitative Data

Qualitative data will be collected through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) to explore behavioural, community, and health system factors influencing identification and vaccination of zero-dose children. A total of four FGDs will be conducted with caregivers of children aged 0–23 months, with each group comprising 6–10 participants. In addition, approximately 10–12 KIIs will be conducted with Village Health Team (VHT) members, health workers, EPI focal persons, local leaders, and district immunisation programme managers. Participants will be purposively selected based on their roles and experience in routine immunisation service delivery. All discussions and interviews will be guided by semi-structured interview guides and audio-recorded with participant consent.

Data Analysis

Data analysis will integrate both quantitative and qualitative approaches to comprehensively assess the effectiveness and implementation performance of the data-linked community–health facility strategy.

Quantitative Data Analysis

Quantitative data obtained from household surveys, health facility immunisation registers, Village Health Team (VHT) household registers, and electronic systems (DHIS2 and eCHIS) will be cleaned, coded, and analysed using Stata version 18 (or SPSS version 26). Data quality checks including range checks, missing value assessment, and logical consistency verification will be conducted prior to analysis.

Descriptive Statistics

Descriptive statistics will be used to summarize the characteristics of the study population and immunization status of children. Continuous variables such as caregiver age will be summarized using means and standard

deviations**,** while categorical variables such as child sex, caregiver education level, and immunization status will be summarized using frequencies and percentages**.**

The prevalence of zero-dose children will be calculated as:

$$\text{Prevalence (\%)} = \frac{\text{Number of children who have not received DTP1}}{\text{Total number of children aged 0–23 months surveyed}} \times 100$$

Spatial distribution of zero-dose children across the study settlements will be visualized using Geographic Information System (GIS) mapping based on GPS coordinates collected during household verification.

Bivariate Analysis

Bivariate analysis will be conducted to examine associations between zero-dose status and potential explanatory variables including demographic, socioeconomic, behavioural, and health system factors.

Statistical tests to be used include:

- Chi-square tests for associations between categorical variables.
- Student's t-tests for comparison of continuous variables between groups.

Associations between categorical variables will be assessed using the Chi-square (χ^2) test, calculated as $x^2 = \sum \frac{(O-E)^2}{E}$ where *O* represents observed frequencies and *E* represents expected frequencies. Differences in continuous variables between groups will be evaluated using the independent samples Student's t-test**,** calculated as $t = \frac{\bar{x_1} - \bar{x_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$, where *t* denotes the test statistic used to assess differences between group means $\bar{x}_1$and $\bar{x}_2$ represent the mean values of groups 1 and 2 respectively, s_1^2 and S_2^2 denote the variances of the two groups, and n_1 and n_2 represent the respective sample sizes. Statistical significance will be considered at $p < 0.05$**.**

Multivariable Analysis

Multivariable logistic regression will be performed to identify independent predictors of zero-dose status among children aged 0–23 months.

The regression model will be expressed as:

$$\text{logit(P)} = \beta 0 + \beta 1 X1 + \cdots + \beta kXk$$

Where:

- P represents the probability of a child being zero-dose.
- $X_1, X_2 \ldots X_k$ represent explanatory variables such as caregiver education, household mobility, distance to health facility, and awareness of immunization services.

Adjusted Odds Ratios (AOR) with 95% confidence intervals will be reported. Statistical significance will be considered at $p < 0.05$**.**

Intervention Effectiveness Analysis

To assess the effectiveness of the data-linked community–health facility strategy, changes in key indicators before and after implementation will be evaluated, including:

- Number of zero-dose children identified.
- Proportion of identified children referred to health facilities.
- Proportion initiating routine immunisation (DTP1 uptake).

Differences between baseline and follow-up measurements will be analysed using paired proportion tests and difference-in-differences analysis where appropriate.

Implementation Outcome Analysis

Implementation outcomes will be assessed using the Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) framework, focusing on:

- Reach: proportion of zero-dose children successfully identified and followed up: $Reach\ (\%) = \frac{\text{Total number of zero–dose children in the target population}}{\text{Number of zero–dose children identified and followed up}}$ x 100
- Effectiveness**:** change in vaccination initiation and completion.
- Adoption**:** proportion of health facilities and VHTs using the data-linkage tools.

- Implementation**:** fidelity of intervention processes including referral tracking and outreach services.
- Maintenance: extent to which the strategy is integrated into routine district immunisation systems.

Qualitative Data Analysis

Qualitative data from Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) will be audio-recorded, transcribed verbatim, and analysed using thematic analysis**.**

The analysis will follow six steps:

1. Familiarization with the data
2. Coding of transcripts
3. Development of themes
4. Review of emerging themes
5. Definition and naming of themes
6. Interpretation and synthesis of findings

Coding will be conducted using NVivo software**.** Themes will focus on barriers and facilitators to immunization uptake, community perceptions of the intervention, and feasibility of scaling the strategy within routine district health systems.

Data Triangulation

Findings from quantitative and qualitative analyses will be triangulated to provide a comprehensive understanding of both the effectiveness and implementation dynamics of the intervention.

This mixed-method integration will strengthen the interpretation of results and enhance the validity of the study conclusions.

Ethical Approval

Ethical approval for this study was obtained from the Hospice Africa Uganda Research Ethics Committee (HAUREC) (Ref No: HAU-2026-214). The study was further registered and cleared by the Uganda National Council for Science and Technology (UNCST) (Permit No: HS7295ES), in accordance with national research regulations governing studies involving human participants in Uganda.

Administrative authorization to conduct the study was obtained from the Wakiso District Health Office and Kira municpality, where the research will be implemented in selected urban informal settlements served by lower-level health facilities providing routine immunisation services.

Written informed consent will be obtained from all adult participants prior to data collection. For caregivers participating on behalf of children aged 0–23 months, consent will be obtained from the primary caregiver responsible for the child. Participation in the study will be entirely voluntary, and participants will be informed of their right to decline participation or withdraw from the study at any time without any consequences.

Confidentiality of participant information will be strictly maintained. Personal identifiers will not be recorded in analytical datasets, and all collected data will be securely stored in password-protected databases accessible only to the research team. Results will be reported in aggregated form to ensure that no individual participant can be identified.

The study will adhere to internationally accepted ethical standards for research involving human participants, including the principles outlined in the Declaration of Helsinki.

Results (Expected Outcomes)

As this study represents an implementation research protocol, the results will evaluate the effectiveness and implementation performance of a data-linked community–health facility strategy designed to improve identification and vaccination uptake among zero-dose children in urban informal settlements.

Specifically, the study will generate evidence on:

1. Baseline prevalence and spatial distribution of zero-dose and under-immunised children in selected urban informal settlements of Wakiso District.

2. Determinants of zero-dose status, including demographic, socioeconomic, behavioural, and health system factors influencing vaccination initiation among children aged 0–23 months.
3. Effectiveness of the data-linked community–health facility strategy, measured through changes in:
    - Identification of zero-dose children.
    - Referral completion rates.
    - Initiation of routine immunisation (DTP1 uptake).
4. Implementation outcomes, including reach, adoption, implementation fidelity, and maintenance of the intervention within routine district immunisation systems, assessed using the RE-AIM implementation framework.

The findings are expected to generate practical implementation evidence to support district-level immunisation microplanning, targeted outreach strategies, and policy decisions aimed at reducing immunisation inequities among children living in urban informal settlements.

Discussion

The study addresses a critical implementation gap in urban immunisation programmes. By integrating community and facility data systems, the intervention aims to improve the visibility and follow-up of missed children.

Previous studies have demonstrated that community health worker-led tracking systems can significantly improve immunisation coverage in complex urban environments [9]. Similar approaches implemented in Tanzania achieved reintegration of more than half of identified zero-dose children within a short period [10].

If effective, the strategy evaluated in this study could inform district-level microplanning and strengthen Uganda's efforts to reduce immunisation inequities.

Conclusion

Urban informal settlements represent a growing challenge for routine immunisation programmes in many low- and middle-income countries. Fragmented data systems and weak community–facility linkages limit the identification and follow-up of zero-dose children.

This study evaluates a practical strategy for integrating community and health facility immunisation data to improve identification, referral, and vaccination uptake among missed children.

Findings from this research will contribute implementation evidence to guide immunisation programme strengthening in urban settings.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

The datasets that will be generated and analysed during the course of this study will include household survey data, qualitative interview transcripts, and routine immunisation programme data obtained from health facility records and national health information systems (DHIS2 and eCHIS). Due to ethical and regulatory restrictions related to participant confidentiality and health system data governance, these datasets will not be publicly available. However, de-identified datasets may be made available from the corresponding author upon reasonable request and subject to approval by the relevant ethical and regulatory authorities, including the Hospice Africa Uganda Research Ethics Committee (HAUREC) and the Uganda National Council for Science and Technology (UNCST).

Author Contributions

Dominic Savio Kakeeto (PhD student in Public Health at Texila American University)

conceptualized the study, developed the research design, conducted the literature review, and prepared the original manuscript draft. Savio also designed the data collection tools and will lead data collection, analysis, and interpretation of the study findings. Prof. Edgar Mulogo Mugema and Prof. Ibrahim Farahat Mohamed El Bayoumy provided academic supervision, methodological guidance, and critical review of the manuscript. All authors reviewed and approved the final version of the manuscript.

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