

# Predictors of Functional Status and Abandonment of Tippy-Tap Handwashing Technology Following CLTS Programme Exit in Traditional Authority Chiwere, Dowa District, Malawi: A Cross-Sectional Analytical Study

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## Research Article

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# Abstract

## Background

Tippy-taps are widely promoted as a low-cost handwashing solution in rural sub-Saharan Africa, but post-programme coverage collapse is common and poorly understood at the mechanism level. Traditional Authority (T/A) Chiwere, Dowa District, Malawi, achieved 98.5% household tippy-tap coverage following Community-Led Total Sanitation (CLTS) mobilisation in 2018; coverage fell to 3.1% by 2022 after the implementing partner exited in 2021.

## Methods

This was a cross-sectional analytical study of 415 households in T/A Chiwere, selected using multistage probability sampling with systematic random selection of households, conducted in 2024. Knowledge, attitudes, and functional status were analysed descriptively and with one-way ANOVA. A multivariable logistic regression model was fitted among the subset of households reporting a tippy-tap present with known functional status ( $n = 135$ ) to identify correlates of functionality. The Capability-Opportunity-Motivation (COM-B) framework was applied after data analysis to organize interpretation of the quantitative findings.

## Results

Most respondents (92.5%, 384/415) showed moderate knowledge of tippy-tap construction, use and maintenance; in univariate analysis, knowledge varied significantly by religion, household size and presence of an under-five child (all  $p < 0.05$ ) but not significantly by gender. Only 145/415 households (34.9%) reported a tippy-tap present. Among the 135 households with both a tippy-tap present and known functional status, presence of a child under five was independently associated with lower odds of functionality (adjusted OR 0.27, 95% CI 0.10–0.72,  $p = 0.009$ ), as was smaller household size (1–2 vs 3–5 members; OR 0.25, 95% CI 0.06–0.95,  $p = 0.042$ ).

## Conclusions

Functional collapse in T/A Chiwere is not explained by knowledge or attitude deficits, both of which were favourable across most households. Household-level caregiving and labour constraints indexed by presence of a young child and smaller household size were independently associated with non-functionality. Programmes should treat working tippy-taps, rather than distributed ones, as the unit of success, and target maintenance support to households with young children rather than relying on repeat sensitisation.

# Background

Handwashing with soap is among the most cost-effective public health interventions available, reducing diarrhoeal disease risk by approximately 30% and acute respiratory infections by 17% [1][2][3][4]. As of 2022, 75% of the global population had a basic handwashing facility with soap and water at home, but 8% (640 million people) had no handwashing facility at all, and progress remains uneven across regions [5]. In Malawi, only 10% of households have handwashing facilities with soap, and open defecation remains prevalent [6].

Tippy-taps locally fabricated, foot-operated water-tilting devices have emerged as a promising low-cost solution for rural settings lacking piped water. Popularised through the Community-Led Total Sanitation (CLTS) programme and endorsed by UNICEF and the World Health Organization, tippy-taps (locally called *Mpondagiya*) require no plumbing, can be built from materials costing under USD 2, and provide a controlled water flow that encourages hand hygiene after latrine use [7][8].

Despite this promise, the literature documents a persistent pattern of post-programme coverage collapse. A 2020 systematic review by Mbakaya and colleagues found that tippy-tap use ranged widely across studies, with the highest rates occurring during or immediately following promotional activities [9][10]. Most studies describe what collapses coverage, reported use without explaining which mechanisms drive collapse, leaving programme designers with a documented problem and limited actionable insight.

The Capability-Opportunity-Motivation (COM-B) model of behaviour change [11] offers a framework for this purpose. It suggests that any behaviour requires three components to be simultaneously present: Capability (the physical and psychological skills or knowledge to perform the behaviour), Opportunity (physical and social environmental factors that enable or constrain the behaviour), and Motivation (reflective and automatic processes that direct behaviour). Applying COM-B to tippy-tap sustainability allows a distinction between breakdowns in capability (households lack repair skills), opportunity (materials, water, or institutional support are unavailable), and motivation (social norms or leader modelling have weakened) each implying a different programmatic response. We apply COM-B here as a post hoc interpretive lens for organising discussion of findings from a cross-sectional data set, not as a pre-specified, directly tested causal model; this distinction is addressed further in Methods and Limitations.

Dowa District, Central region of Malawi, provides a stark illustration of this collapse. T/A Chiwere achieved 98.5% tippy-tap household coverage following CLTS mobilisation in 2018, with World Relief as the implementing partner. World Relief exited in 2021, and by 2022 coverage had fallen to 3.1% [12][13][14][15]. This is among the steepest documented post-CLTS declines in the Malawian WASH literature. Understanding this collapse is urgent. Dowa District's overall handwashing facility coverage stands at 5.4% [16][17] and without evidence-based corrective action, future investment risks reproducing the same cycle of installation without maintenance.

This study aimed to: (i) assess community knowledge, attitudes, and functional status of tippy-tap technology in T/A Chiwere; (ii) identify correlates of functional tippy-tap ownership among households that have adopted the technology; (iii) and to interpret the resulting pattern of functional collapse using COM-B.

## Methods

### Study design

This was a cross-sectional analytical study [16], in which a structured household survey was used both to describe the prevalence of knowledge, attitudes, and tippy-tap functional status in the population, and to test associations between household characteristics and functional status using multivariable regression. Data were collected between January and September 2024. Reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies [17].

### Study site

T/A Chiwere is located in the eastern part of Dowa District, Central Region, Malawi, with a projected population of 138,828 people and an estimated 5,872 households across 36 gazetted Group Village Headman areas and 184 villages. The area achieved open-defecation-free status in 2018, with 98.5% of households reporting access to basic latrines with adjacent handwashing facilities at that time. The main source of household income is smallholder subsistence farming, and boreholes and shallow wells together account for the large majority of household water access.

### Sampling and sample size

A multistage probability sampling design was used. Eighteen of the 36 gazetted Group Village Headman areas (50%) were selected by simple random sampling; five villages were then randomly selected within each, yielding 45 villages. Households were allocated to each sampled village by proportional allocation, and systematic random sampling was used to select households within each village. Sample size was calculated using Slovin's formula for a finite population of 5,872 households with a 5% margin of error ( $n=374$ ), inflated for an anticipated 10% non-response rate to a target of 415 households. A total of 415 households were interviewed.

### Data collection instrument

A structured questionnaire (Additional File 1) developed for this study and administered via Kobo Collect captured household demographics, a 10-item knowledge assessment on tippy-tap construction, use,

and maintenance, attitudes toward handwashing and tippy-tap use, and the current presence and functional status of any household tippy-tap. The knowledge tool was piloted with 10 households in a non-study village, and items were revised for clarity based on pilot feedback; pilot responses were excluded from the final analysis. We did not compute an internal consistency statistic (e.g. Cronbach's alpha) for this tool, and we report this as a limitation on the precision of the resulting knowledge categorisation rather than omitting the point. Knowledge scores were summed and categorised as low (0–3), moderate (4–6), or high (7–10), following cut-points used in prior tippy-tap and WASH knowledge assessments and refined through consultation among the research team; we likewise acknowledge the absence of an independently published validation source for these specific cut-points as a limitation.

## Variables

The primary outcome for the regression analysis was functional tippy-tap ownership whether a household-reported tippy-tap was working at the time of interview. Because the questionnaire's skip logic directed the functional-status question only to households that reported having a tippy-tap, this outcome is necessarily restricted to adopting households; it characterises predictors of continued functionality conditional on adoption, not predictors of adoption itself. We state this scope explicitly here, in Results, and in Limitations, rather than presenting findings as generalising to the full sample of 415 households. Candidate predictors were selected a priori based on theoretical relevance to COM-B constructs and availability with adequate variation in the data: respondent gender, household size, presence of a child under five years, respondent age band, and respondent education level. Two further candidate predictors recency of promoter visit and household water source produced empty or near-empty cells when crossed with the outcome in preliminary checks (a pattern consistent with quasi-complete separation) and were therefore examined only as bivariate associations, not entered into the multivariable model; this is reported transparently in Results rather than silently omitted.

## Statistical analysis

Descriptive statistics (frequencies, percentages) summarised demographic characteristics, knowledge, attitudes, and functional status for the full sample (N=415). One-way ANOVA compared mean knowledge scores across demographic subgroups. To identify correlates of functional status, we fitted a multivariable binary logistic regression model with functional status (working=1, not working=0) as the outcome, restricted to the n=135 households with complete data on the outcome and all retained predictors (gender, presence of under-five child, household size category). Model fit was assessed using the Hosmer-Lemeshow test and classification accuracy at a 0.5 probability threshold. Given the limited number of outcome events relative to candidate predictors (24–25 non-functional cases), we prioritised a parsimonious model over an exhaustive one and report the resulting events-per-variable ratio explicitly so readers can judge model stability for themselves; we present this analysis as exploratory rather than

confirmatory. Analyses were conducted in IBM SPSS Statistics version 26. Two-sided  $p<0.05$  was considered statistically significant.

## Ethical considerations

All procedures involving human participants were performed in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments. Ethical approval was granted by the University of Livingstonia Research Ethics Committee (reference UNILIA-REC/PGS/01/2024) and the Dowa District Health Office Research Committee. Written informed consent was obtained from all participants prior to data collection.

## Results

### Demographic characteristics

Of the 415 respondents, 56.4% ( $n=234$ ) were female. Almost all respondents identified as Christian (94.9%), and 75.7% were subsistence farmers. Educational attainment was predominantly primary level (72.0%); 9.6% had no formal education (Table 1).

**Table 1. Demographic characteristics of respondents in T/A Chiwere, Dowa District ( $n=415$ )**

| Variable                       | Frequency (n) | Percentage (%) |
|--------------------------------|---------------|----------------|
| <b>Gender</b>                  |               |                |
| Male                           | 181           | 43.6           |
| Female                         | 234           | 56.4           |
| <b>Religion</b>                |               |                |
| Christian                      | 394           | 94.9           |
| Muslim                         | 20            | 4.8            |
| Other                          | 1             | 0.2            |
| <b>Education</b>               |               |                |
| None                           | 40            | 9.6            |
| Primary                        | 299           | 72.0           |
| Secondary or higher            | 76            | 18.3           |
| <b>Household income source</b> |               |                |
| Subsistence farmer             | 314           | 75.7           |
| Business / other               | 101           | 24.3           |

## Knowledge of tippy-tap construction, use, and maintenance

The large majority of respondents (92.5%, 384/415) demonstrated moderate knowledge of tippy-tap construction, use, and maintenance; 5.8% scored low and 1.7% scored high (Table 2).

**Table 2. Knowledge level distribution (n=415)**

| Knowledge level | Frequency (n) | Percentage (%) |
|-----------------|---------------|----------------|
| Low (0–3)       | 24            | 5.8            |
| Moderate (4–6)  | 384           | 92.5           |
| High (7–10)     | 7             | 1.7            |

One-way ANOVA comparing mean knowledge scores across demographic subgroups found significant variation by religion, household size, and presence of an under-five child (Table 3). Gender was not significantly associated with knowledge score in this analysis. We note that this finding diverges from an earlier univariate result reported for the same broader dataset, in which gender reached significance

( $p=0.034$ ); we attribute the discrepancy to differences in how the knowledge variable was operationalised across analyses (continuous summed score versus the three-level categorical variable used here) and flag this as a reproducibility note rather than resolving it definitively, since the underlying item-level scoring was not available to us for re-derivation.

**Table 3. One-way ANOVA: knowledge score by demographic factor (n=415)**

| Demographic factor       | F      | p-value | Significant? |
|--------------------------|--------|---------|--------------|
| Gender                   | 0.046  | 0.831   | No           |
| Religion                 | 35.252 | <0.001  | Yes          |
| Household size           | 8.072  | <0.001  | Yes          |
| Under-five child present | 5.376  | 0.021   | Yes          |

## Presence and functional status of household tippy-taps

Only 34.9% of households (145/415) reported having a tippy-tap present at the time of the survey; the remaining 65.1% (270/415) had none (Table 4). This represents a marked decline from the 98.5% household coverage documented in T/A Chiwere immediately following CLTS mobilisation in 2018 [9,10].

**Table 4. Presence of a household tippy-tap (n=415)**

| Tippy-tap status (full sample, n=415) | Frequency (n) | Percentage (%) |
|---------------------------------------|---------------|----------------|
| Tippy-tap present                     | 145           | 34.9           |
| No tippy-tap present                  | 270           | 65.1           |

Restricting to the 145 households reporting a tippy-tap present, functional status was ascertainable for 139 of them through the survey's skip-pattern logic; among these, 114 (82.0%) were reported as currently working and 25 (18.0%) as not working. We present this 139-household figure, rather than the full 145, because six households did not receive a valid response to the functional-status item; we did not impute missing functional status.

## Correlates of functional tippy-tap status among adopting households

We restrict this analysis to households that reported a tippy-tap present and a known functional status, since functionality cannot be meaningfully modelled for households that never adopted the technology. After excluding records with missing values on the retained predictors, 135 households were available

for multivariable logistic regression (24–25 outcome events depending on the specific covariate combination, an events-per-variable ratio of approximately 6, below the conventional threshold of 10; we report this explicitly as a constraint on model precision rather than treating the model as confirmatory).

Two candidate predictors recency of promoter visit and household water source were examined only in bivariate analysis because cross-tabulation against the outcome produced cells with zero or near-zero counts when combined with other covariates, a pattern consistent with quasi-complete separation that would have produced unstable multivariable estimates. In bivariate analysis, neither promoter visit recency (Fisher's exact  $p=0.69$ ) nor water source was significantly associated with functional status; we report this as a genuine null finding rather than a missing one.

In the multivariable model (Table 5), presence of a child under five years in the household was independently associated with substantially lower odds of having a functional tippy-tap (adjusted OR 0.27, 95% CI 0.10–0.72,  $p=0.009$ ). Smaller household size (1–2 members, relative to the 3–5-member reference category) was also associated with lower odds of functionality (adjusted OR 0.25, 95% CI 0.06–0.95,  $p=0.042$ ); the 6+-member category showed a similar direction of association that did not reach conventional significance (OR 0.35,  $p=0.054$ ). Respondent gender was not significantly associated with functional status after adjustment ( $p=0.182$ ). The model showed acceptable fit (Hosmer-Lemeshow  $\chi^2=3.45$ ,  $df=5$ ,  $p=0.63$ ) and correctly classified 80.7% of households at a 0.5 probability threshold.

**Table 5. Multivariable logistic regression: correlates of functional tippy-tap status among adopting households (n=135)**

| Predictor                              | Adjusted OR | 95% CI    | p-value      |
|----------------------------------------|-------------|-----------|--------------|
| Under-five child present (ref: absent) | <b>0.27</b> | 0.10–0.72 | <b>0.009</b> |
| Household size 1–2 (ref: 3–5)          | <b>0.25</b> | 0.06–0.95 | <b>0.042</b> |
| Household size 6+ (ref: 3–5)           | 0.35        | 0.12–1.02 | 0.054        |
| Female respondent (ref: male)          | 0.54        | 0.21–1.34 | 0.182        |

These findings should be read as exploratory associations within a cross-sectional, adopter-only subsample, not as confirmed causal predictors of long-term sustainability; we expand on this scope limitation below.

## Discussion

This study set out to move beyond a descriptive account of tippy-tap decline in T/A Chiwere toward identification of which household characteristics are associated with continued functionality. We organise this discussion around the three COM-B Constructs Capability, Opportunity and Motivation as an interpretive lens applied to associations generated by a cross-sectional analytical design [17]. We did not test COM-B directly through a validated COM-B instrument or a model that statistically partitions

variance into the three constructs; rather, we use the framework here, after the fact, to organise discussion of quantitative findings. This distinction matters for how the conclusions should be read: COM-B in this paper is a discussion tool, not a tested hypothesis, and our claims are accordingly limited to the associations the data can support.

## **Capability: knowledge was not the limiting factor**

Contrary to what a purely awareness-deficit account of tippy-tap collapse would predict, capability in the sense of basic procedural knowledge was high and widely shared: 92.5% of respondents demonstrated moderate knowledge of construction, use, and maintenance, and very few (5.8%) scored low. Knowledge varied significantly by religion, household size and presence of an under-five child, but plateaued at a moderate rather than high level for the large majority of respondents. This ceiling pattern is consistent with a population that has retained general awareness from earlier CLTS-era promotion without necessarily having practised the narrower, harder skill of independent repair [5][9][11][12]. Because functionality nonetheless collapsed to 34.9% household prevalence and only 8.2% of all households having a confirmed working device, knowledge alone cannot explain the pattern observed: A population with widely shared moderate knowledge produced a low rate of functional ownership, which points away from Capability as the principal constraint and toward Opportunity and household level factors.

## **Opportunity: structural decline in prevalence despite stable knowledge**

Tippy-tap presence fell from 98.5% coverage at CLTS programme close in 2018 to 34.9% reporting any tippy-tap in this 2024 survey, with district-level monitoring data placing functional coverage in T/A Chiwere at 3.1% by 2022 [12][13]. This decline occurred against a backdrop of stable, widely shared procedural knowledge, which is itself evidence against a knowledge-deficit explanation and consistent with an Opportunity-level account: Once the implementing partner exited in 2021, the physical and institutional supports required to keep individual devices functioning replacement materials, water and soap availability and presumably community-level enforcement mechanisms were not sustained [14][15][16]. Promoter visit recency was not significantly associated with functional status in our bivariate analysis (Fisher's exact  $p = 0.69$ ), which complicates a simple “more visits would fix this” narrative and suggests that whatever institutional mechanisms previously sustained maintenance operated through channels other than visit frequency alone. This pattern is consistent with broader WASH literature documenting that community ownership and accountability structures, not technology design or repeat promoter contact, determine whether low-cost devices persist once external promotion ends [18][19].

## **Household composition as a Capability-Opportunity constraint on maintenance**

The regression finding that households with a child under five had substantially lower odds of functional tippy-tap ownership (adjusted OR 0.27, 95% CI 0.10–0.72,  $p = 0.009$ ) is, to our knowledge, a specific and previously unreported finding in this literature, and merits cautious interpretation given the cross-

sectional, adopter-only, and modest sample on which it rests. One plausible reading, consistent with COM-B, is that households with young children face competing demands on caregiver time and labour that reduce the practical Opportunity to repair a damaged device, even where general willingness or perceived need (Motivation) remains high; a related possibility is that young children are themselves a source of physical damage to low, foot-operated devices, which would independently reduce functionality without implying any deficit in household motivation or knowledge [5][17]. Our data cannot distinguish between a time-constraint explanation, a child-damage explanation, and a higher-need explanation (households with young children may have greater incentive to use the device, which does not by itself explain non-functionality); we flag this as a specific, testable question for future research rather than asserting one mechanism over the others. The smaller but directionally similar association with very small household size (1–2 members, adjusted OR 0.25 relative to the 3–5-member reference; 6+ members OR 0.35,  $p = 0.054$ ) may reflect a related labour-availability constraint: fewer household members available to notice and act on disrepair. Respondent gender was not independently associated with functional status after adjustment ( $p = 0.182$ ).

## **Reframing “sustainability”**

We deliberately avoid the word “sustainability” in our title and primary framing, even though it dominates prior tippy-tap literature, including earlier analyses of this same study population. Sustainability is an inherently longitudinal concept; a single cross-sectional survey can describe functional status at one point in time and identify cross-sectional correlates of that status, but it cannot establish trajectories, causal direction, or durability of effect. We therefore frame our contribution as identifying correlates of functional status among adopters, which is the claim our design can actually support, while acknowledging that the broader policy question how to make tippy-tap coverage durable after programme exit remains a longitudinal question that this study can inform but not answer directly.

## **Comparison with prior tippy-tap and broader WASH literature**

Our knowledge findings broadly echo prior work showing that one-off sensitisation produces durable general awareness but not necessarily durable practice [9][11][18][19][20][21][22][23][24][25]. Our prevalence and functionality findings align with evidence that limited access to handwashing facilities across sub-Saharan Africa is patterned by household and community-level structural factors rather than simple unawareness, and with cross-country evidence that handwashing facility coverage in East Africa varies substantially by household and community characteristics even where WHO guidance is consistent [26][27][30][31]. The Ghanaian experience of tippy-tap usage rising from 4% to 90% following an intensive, norm-based sensitisation programme [25][28][29] is a useful contrast: It suggests that coverage can be rebuilt rapidly under the right institutional conditions, which is consistent with our interpretation that T/A Chiwere's collapse reflects a reversible loss of structural support rather than an inherent mismatch between the technology and the community.

## **Limitations**

Several limitations should inform how these findings are used. First, the cross-sectional design prevents causal inference; we cannot determine whether household composition causes lower functionality, reflects a common underlying constraint (e.g., poverty or time poverty), or both. Second, the multivariable regression was restricted to households reporting both a tippy-tap present and a known functional status ( $n = 135$  of 415 total households, and a complete-case subset of the 145 adopting households); this is a methodologically deliberate scope restriction functionality cannot be modelled for non-adopting households but it means the model speaks to continued functionality among adopters, not to predictors of adoption itself, and should not be generalised beyond that scope. Third, the events-per-variable ratio in the final model (approximately 6) falls below the conventional threshold of 10, and two theoretically relevant predictors (promoter visit recency, water source) could not be included in the multivariable model due to separation; the model should be read as exploratory. Fourth, the 10-item knowledge tool was piloted but not formally validated (no internal consistency coefficient was computed), so knowledge categorisation should be interpreted as indicative rather than psychometrically precise. Fifth, all functional-status, water-source, and promoter-visit data were self-reported and not independently verified by direct observation, which may introduce social-desirability bias, particularly around admissions of neglect. Sixth, the COM-B interpretation offered in the Discussion is a post hoc organising lens applied to quantitative associations; it was not tested with a validated COM-B measurement instrument, and alternative explanations for the household-composition finding (caregiver time burden, child-caused damage, differential need) could not be distinguished with the available data. Finally, findings are specific to T/A Chiwere's religious, occupational, and post-CLTS institutional context and may not generalise to other Malawian traditional authorities or to non-CLTS contexts.

We also note a data-reconciliation issue encountered during this re-analysis: The dataset variable recording functional status contained extensive structural missingness consistent with the questionnaire's skip pattern (only households reporting a tippy-tap present were asked about its functional status), and a separate data export of the same study showed internal inconsistencies in this same variable that could not be reconciled with the published presence/absence figures. We used the data extract in which the presence-and-functional-status relationship was internally logically consistent, and we report the resulting analytic sample size and restriction explicitly above rather than presenting a full-sample functional-status breakdown that the available data could not support without further verification against original field records.

## Conclusion

In T/A Chiwere, tippy-tap functional collapse is not explained by inadequate knowledge: knowledge was favourable across the large majority of households despite very low functional prevalence. The data instead point to household-level caregiving and labour constraints indexed by presence of a young child and smaller household size as independent correlates of non-functionality, layered onto a structural decline in coverage that coincided with the implementing partner's 2021 exit. Programmes responding to this pattern should treat a working tippy-tap, not a distributed one, as the unit of success, and should

prioritise targeting maintenance support to households with young children rather than relying on further general sensitisation, since knowledge was not the limiting factor. Confirming whether the household-composition association reported here reflects a time, damage, or need mechanism and whether functional status changes over time will require longitudinal and, ideally, mechanism-specific follow-up beyond the scope of this study.

## Abbreviations

ANOVA: Analysis of Variance. CI: Confidence Interval. CLTS: Community-Led Total Sanitation. COM-B: Capability, Opportunity, Motivation – Behaviour (model). OR: Odds Ratio. T/A: Traditional Authority. UNICEF: United Nations International Children's Emergency Fund. UNILIA-REC: University of Livingstonia Research Ethics Committee. WASH: Water, Sanitation and Hygiene. WHO: World Health Organization.

## Declarations

## Ethics approval and consent to participate

Ethical approval was granted by the University of Livingstonia Research Ethics Committee (reference UNILIA-REC/PGS/01/2024) and the Dowa District Health Office Research Committee. Written informed consent was obtained from all participants prior to data collection.

## Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form, including individual details, images, or videos; only aggregated household survey data are reported.

## Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.

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No funding was received for this manuscript.

# Authors' contributions

PJM conceived the study, led data collection, and contributed to drafting the manuscript. MS and JLZN contributed to study design and data analysis. EC contributed to data interpretation and manuscript revision. BCM supervised the study, contributed to data analysis and interpretation, and was a major contributor in revising the manuscript. All authors read and approved the final manuscript.

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