

Evaluating Technical Efficiency of Voluntary Medical Male Circumcision Service Delivery In Zambia: Data Envelopment Analysis Approach

Nanzaluka Hatontola

tontonanzil10@gmail.com

University of Zambia

Wilbroad Mutale

University of Zambia

Chris Mweemba

University of Zambia

Mwimba Chewe

University of Zambia

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Abstract

Background

HIV remains a major public health challenge in sub-Saharan Africa, and voluntary medical male circumcision has been shown to reduce the risk of female-to-male HIV transmission by up to 60%. Zambia adopted circumcision as part of its national HIV prevention strategy in 2007, yet coverage has remained below the 80% target. With donor funding tightening and Zambia taking on more of its own HIV financing, getting the most out of available resources has never been more important. Despite this, no study had looked at how efficiently Zambian health facilities actually deliver circumcision services.

Methods

We conducted a cross-sectional analysis of secondary data from the Global Fund TB/HIV 2023 survey, covering 67 health facilities that provided VMMC services in 2022. Efficiency was assessed using input-oriented Data Envelopment Analysis (DEA) under both Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) models. Inputs were the number of days per week VMMC services were offered, frequency of outreach activities, and involvement of community-based volunteers. Outputs were the number of circumcisions performed, and post-operative follow-up visits completed.

Results

Facilities performed a mean of 584 circumcisions (median = 298; IQR = 709) and 486 follow-up visits (median = 168; IQR = 404). Under the VRS model, 38 facilities (55.9%) scored below 0.50, and only 14 (20.6%) achieved full efficiency. The CRS model revealed greater inefficiency: 45 facilities (67.1%) scored below 0.50, with just 8 (11.9%) fully efficient. Scale efficiency was comparatively high, with 55 facilities (82.0%) scoring between 0.50 and 0.99.

Conclusion

VMMC service delivery in Zambia is characterized by substantial technical inefficiency driven by suboptimal resource utilization. Reorganizing service delivery and targeting management interventions at underperforming facilities could increase VMMC output without additional resource investment.

1. Introduction

Sub Saharan Africa bears the greatest global burden of HIV, with approximately 70% of all people living with HIV residing in this region. Voluntary medical male circumcision (VMMC) is one of the most effective biomedical tools available to reduce this burden. Three randomized controlled trials in South Africa, Kenya, and Uganda demonstrated that VMMC reduces female to male HIV transmission by 50%

to 60%¹⁻³. A Cochrane systematic review pooling all three trials confirmed a relative risk reduction of 38% to 66% over 24 months, with very low rates of adverse events⁴. On this basis, WHO and UNAIDS recommended VMMC scale up in 14 priority countries in eastern and southern Africa, including Zambia⁵. By 2014, over 9 million procedures had been performed across these countries, representing 43% of the estimated target for 80% coverage⁵.

Zambia adopted VMMC as a core HIV prevention strategy in 2007 and has since delivered services through fixed facilities, outreach activities, and high volume campaigns. Adult HIV prevalence among persons aged 15 to 49 has declined over time, from roughly 14% in the early 2000s to about 11% by 2021, while viral load suppression among people living with HIV improved substantially from 59% to 86% between 2016 and 2021⁶. However, these national gains have been uneven. Prevalence among young urban men has shown less favourable trends compared to young women⁷. Modelling analyses suggest that reaching 80% VMMC coverage in males aged 15 to 49 could avert over 300,000 infections in Zambia⁸. Yet in practice, circumcision coverage in 42 rural communities rose only from 11.5% to 18.0% between 2013 and 2015, with persistent gaps in both demand and supply⁹.

As global funding for HIV begins to stay the same and Zambia takes on more responsibility for financing its own response, it becomes increasingly important to deliver VMMC services in a more efficient and effective way.. Multi country costing studies have shown that VMMC unit costs vary widely across facilities and that significant efficiency gains are achievable through task shifting, service integration, and increased client volume⁹. Studies using data envelopment analysis (DEA) to measure facility level technical efficiency in other African settings have confirmed this variation. In Kenya's Nyanza region, mean scale efficiency improved significantly among outreach facilities¹⁰, while a four country DEA study of 108 facilities found wide variation in efficiency with no clear link to management practices¹¹. Analyses of surgical processes across Kenya, South Africa, Tanzania, and Zimbabwe further showed that task sharing and use of electrocautery reduced provider time per client without compromising quality.

In Zambia, however, the technical efficiency of VMMC service delivery has not been systematically assessed. This study used DEA to evaluate the technical efficiency of 67 VMMC health facilities in Zambia, identify performance gaps and scale inefficiencies, and generate evidence to support more strategic resource allocation as the country works to sustain and expand coverage.

2. Methods

2.1. Study Design and Setting

This study employed a cross-sectional quantitative design using secondary data analysis to assess the technical efficiency of Voluntary Medical Male Circumcision (VMMC) service delivery across health facilities in Zambia for the calendar year 2022.

Data were sourced from the Global Fund TB/HIV 2023 survey, a nationally representative dataset covering health facilities across all ten Zambian provinces. Sites were selected through a two-stage stratified sampling design: in the first stage, 30 districts were purposively selected across all provinces based on high tuberculosis case notification rates, given the established epidemiological link between tuberculosis and HIV. In the second stage, health facilities within selected districts were stratified by location (urban, peri-urban, and rural) and facility level; six facilities were randomly selected per district, with deliberate oversampling of rural areas to ensure geographic representativeness. Of the 183 facilities initially enrolled in the survey, 67 facilities with complete data on all DEA input and output variables were retained for analysis and treated as Decision-Making Units (DMUs).

2.2. Data Envelopment Analysis Framework

The primary analytical method was Data Envelopment Analysis (DEA), a non-parametric linear programming technique that measures the relative efficiency of DMUs transforming multiple inputs into multiple outputs (Charnes, Cooper and Rhodes, 1978; Banker, Charnes and Cooper, 1984). DEA constructs an empirical best-practice production frontier from the most efficient facilities in the sample; each facility receives an efficiency score between 0 and 1 (or equivalently 0–100%), reflecting its performance relative to this frontier.

An *input-oriented* model was selected because the primary policy objective in resource-constrained Zambian public health is to minimize inputs required to achieve a given service output. This orientation quantifies the proportional reduction in inputs that each facility could realize without compromising its current level of VMMC service delivery, thereby identifying the fiscal space available from efficiency gains. Two DEA model variants were estimated:

1. Constant Returns to Scale (CRS; CCR model). This assumes all DMUs operate at optimal scale. The CRS efficiency score captures overall (global) technical efficiency, reflecting the combined contribution of managerial competence and scale effects.

2. Variable Returns to Scale (VRS; BCC model). This relaxes the constant-scale assumption by incorporating a convexity constraint, permitting increasing, constant, or decreasing returns to scale within the sample. The VRS score measures pure technical efficiency (PTE), the managerial ability to convert inputs into outputs independent of facility size.

Scale efficiency (SE) was derived as the ratio of the CRS to the VRS score ($SE = CRS\ TE / VRS\ TE$). A scale efficiency score of 1 indicates that the facility is operating at its most productive scale size; values below 1 denote scale inefficiency arising from either increasing or decreasing returns to scale.

Statistical analyses were performed using R version 4.5.1 and the *rDEA* package. DEA efficiency scores for each facility were computed, and descriptive statistics were generated to summarize score distributions. Benchmarking analysis identified facilities forming the efficiency frontier and quantified the frequency with which each was referenced as a peer comparator for inefficient facilities.

2.3. Variable Selection and Specification

The specification of input and output variables adhered to established efficiency analysis methodologies in the health sector and was guided by the Theory of Production, which conceptualizes health facilities as productive units transforming scarce inputs into measurable service outputs (Hollingsworth, 2008; Coelli et al., 2005). Variables were selected to closely reflect the operational and organizational context of VMMC service delivery in Zambia. The input and output variables used in the DEA model are summarized in Table 1.

Table 1
Input and output variables used in the Data Envelopment Analysis model.

Code	Variable	Description	Justification
Inputs			
X ₁	VMMC service days per week	Number of days per week VMMC services were offered at the facility	Reflects service availability and scheduling capacity; a key operational driver of output volume
X ₂	Outreach sessions conducted	Number of community mobilization and outreach activities conducted in 2022	Captures community engagement efforts central to demand creation for VMMC services
X ₃	Community-based volunteers (CBVs) assigned	Number of CBVs assigned to VMMC service delivery and mobilization	Represents dedicated human resources supporting outreach, client mobilization, and follow-up
Outputs			
Y ₁	VMMC procedures performed	Total number of voluntary medical male circumcision surgeries performed in 2022	Primary service delivery output and direct measure of programme performance
Y ₂	Post-operative follow-up visits	Number of clients returning for post-operative wound review and care	Reflects continuity of care, a secondary output capturing service quality and patient safety
Note. CBV = community-based volunteer; VMMC = voluntary medical male circumcision. Variable selection adhered to Bessent and Bessent (1979) criteria, including realistic input–output relationships, directional monotonicity, and absence of zero elements. Zero values in outreach sessions were substituted with 0.01 to satisfy DEA model requirements.			

Three input variables were specified. Service days per week (X₁) reflects scheduling capacity and operational intensity at each facility. Outreach sessions conducted (X₂) captures community mobilization investments, which are critical demand-generation activities for VMMC. Community-based volunteers assigned (X₃) represents the dedicated human resource component for client mobilization and follow-up support. Two output variables were defined. The number of VMMC procedures performed (Y₁) constitutes the primary service delivery output. Post-operative follow-up visits (Y₂) serves as a secondary output reflecting continuity of care and service quality. No a priori weight restrictions were imposed on variables.

2.4. Sample Size

Of the 183 facilities in the original survey, 67 facilities with complete data on all input and output variables were included in the DEA. Full enumeration of eligible facilities was used rather than random sampling. For DEA, minimum sample size recommendations require that the number of DMUs be at least three times the sum of the number of inputs and outputs, that is, at minimum $3 \times (3 + 2) = 15$ DMUs. The sample of $N = 67$ substantially exceeded this threshold, providing a statistically adequate basis for DEA estimation.

2.5. Ethical Considerations

Ethical approval was granted by the University of Zambia Biomedical Research Ethics Committee (UNZABREC). Administrative clearance was obtained from the Zambia Ministry of Health and the custodians of the Global Fund dataset. All data were fully anonymized prior to analysis; facility-level identifiers were de-identified, and data were stored in password-protected files accessible only to the research team. Given the exclusive use of pre-existing, de-identified secondary data, a waiver of individual informed consent was granted by UNZABREC.

This was not a clinical trial hence the clinical trial number was not applicable.

3. Results

3.1. Descriptive Statistics of Facility Inputs and Outputs

The analysis was conducted on 67 health facilities delivering VMMC services in Zambia in 2022. Table 2 presents the descriptive statistics for all input and output variables. Considerable variability was observed in service outputs. On average, facilities performed 584 circumcisions per year (median = 298; interquartile range [IQR] = 709; standard deviation [SD] = 752), indicating a right-skewed distribution with a small proportion of high-volume facilities substantially elevating the mean. Post-operative follow-up visits averaged 486 per facility (median = 168; IQR = 404; SD = 774), similarly exhibiting high variability.

Input utilization also varied markedly across facilities. VMMC services were offered on average 4.1 days per week (median = 5; IQR = 4; SD = 2.0), suggesting that approximately half of facilities offered daily or near-daily services. Outreach activities were highly variable, with a mean of 16.8 sessions per year (median = 4; IQR = 11; SD = 41.4), indicating that a small number of facilities conducted intensive outreach programmes while the majority held relatively few sessions. Community-based volunteers averaged 3 per facility (median = 2; IQR = 2; SD = 8.0), with similarly high dispersion.

Table 2
Descriptive statistics of DEA input and output variables for VMMC service delivery across 67 health facilities in Zambia, 2022.

	Variable	Mean	SD	Median	IQR	Range
Outputs						
Y ₁	VMMC procedures performed	584	752	298	709	1–10,073
Y ₂	Post-operative follow-up visits	486	774	168	404	1–8,640
Inputs						
X ₁	VMMC service days per week	4.1	2.0	5.0	4	1–7
X ₂	Outreach sessions conducted	16.8	41.4	4.0	11	0–320
X ₃	CBVs assigned	3.0	8.0	2.0	2	0–65
Note. CBV = community-based volunteer; IQR = interquartile range; SD = standard deviation; VMMC = voluntary medical male circumcision. Variable codes correspond to those in Table 1.						

3.2. Technical Efficiency Scores

Table 3 summarizes the distribution of VRS, CRS, and scale efficiency scores across the 67 facilities. Under the VRS model, which isolates pure technical efficiency by excluding scale effects, 38 facilities (56.7%) recorded efficiency scores below 0.50. This implies that the majority of facilities were operating less than half the output that could theoretically be achieved with their current inputs if managed as efficiently as best-practice peers. Only 14 facilities (20.9%) were fully VRS-efficient (score = 1.00), indicating a small proportion operating on the best-practice frontier.

The CRS model revealed even greater inefficiency. Under CRS assumptions, 45 facilities (67.2%) recorded scores below 0.50, and only 8 facilities (11.9%) achieved full CRS efficiency. The consistently lower CRS scores relative to VRS scores confirm that a portion of inefficiency was attributable to scale, facilities were not uniformly operating at their optimal productive size.

Scale efficiency, by contrast, was considerably higher. Only 4 facilities (6.0%) recorded scale efficiency scores below 0.50, while 55 facilities (82.1%) operated within the 0.50–0.99 range, indicating near-optimal scale utilization. Only 8 facilities (11.9%) achieved perfect scale efficiency. The divergence between low technical efficiency and relatively high scale efficiency suggests that operational and managerial inefficiency, rather than inappropriate facility size, was the dominant source of underperformance in the sample.

Table 3

Distribution of VRS, CRS, and scale efficiency scores among 67 VMMC facilities in Zambia, 2022 (N = 67).

Efficiency score category	VRS efficiency n (%)	CRS efficiency n (%)	Scale efficiency n (%)
< 0.50	38 (56.7)	45 (67.2)	4 (6.0)
0.50–0.99	15 (22.4)	14 (20.9)	55 (82.1)
1.00 (fully efficient)	14 (20.9)	8 (11.9)	8 (11.9)
Total	67 (100)	67 (100)	67 (100)
Note. CRS = constant returns to scale; VRS = variable returns to scale. Efficiency scores range from 0 (fully inefficient) to 1.00 (fully efficient). Scale efficiency is calculated as the ratio of the CRS to the VRS efficiency score.			

3.3. Benchmarking Analysis

Benchmarking in DEA identifies efficient facilities, those on the production frontier, that serve as peer comparators for less efficient DMUs. Table 4 presents all facilities that appeared at least once in the reference sets of inefficient facilities, ranked by the frequency of their appearance.

Thirteen facilities appeared in the efficiency reference sets. Facility 51 was the most influential benchmark, appearing in the reference sets of 21 facilities, indicating that its configuration of inputs and outputs was most frequently identified as a realistic performance target for underperforming sites. Facility 68 was the second most frequently cited benchmark (18 occurrences), followed by facilities 5508015, 55080015, and 050, each appearing 15 times. Facility 080 appeared 13 times, and 90030011 ten times. The remaining six benchmark facilities appeared between 2 and 9 times.

The concentration of benchmarking influence among a small cluster of facilities, particularly the top three, which together account for a disproportionate share of reference appearances, suggests that best practices in VMMC service delivery are not evenly distributed across the sample but are localized within a small number of high-performing facilities. These facilities represent attainable, domestically grounded performance targets that can realistically inform service delivery improvements across the broader VMMC network.

Table 4

Benchmark facilities and frequency of appearance in DEA reference sets among 67 VMMC facilities in Zambia, 2022.

Facility code	Benchmark frequency (no. of reference appearances)	Interpretation
51	21	Most influential benchmark; resource configuration identified as optimal reference for 21 facilities
68	18	Second most frequent peer; consistently identified as a high-performing reference facility
5508015	15	Third-tier benchmark with strong peer influence across multiple DMUs
55080015	15	Co-equal peer influence; likely reflects similar efficient operational profile to facility 5508015
050	15	Frequently referenced; contributes to efficiency frontier definition
080	13	Moderate peer influence; among the top six most-referenced benchmark facilities
90030011	10	Identified as an efficient peer for 10 facilities
160	9	Moderate influence on the efficiency frontier
90030006	8	Contributes to benchmarking for eight underperforming facilities
10030008	6	Lower-frequency benchmark; provides peer guidance for six facilities
90030016	4	Marginal frontier influence
203027	2	Infrequent benchmark; minimal frontier influence
60070013	2	Infrequent benchmark; minimal frontier influence
Note. DMU = decision-making unit. Benchmark frequency indicates the number of times a facility appeared in the VRS efficiency reference set of inefficient facilities. Facilities with higher frequencies exert greater influence on the efficiency frontier and serve as primary peer comparators.		

4. Discussion

This study used data envelopment analysis to measure how efficiently 67 health facilities in Zambia deliver voluntary medical male circumcision services under both constant and variable returns to scale. The results suggest that many facilities are not using their existing resources as well as they could, even though most are operating at a broadly appropriate size. This pattern points to problems in the way services are organised and managed rather than in the scale of operations, which is similar to what has been reported for other health and HIV related services in Zambia and across sub Saharan Africa^{12–14}.

In terms of technical efficiency, most facilities in this study were operating well below the best performing sites. Under variable returns to scale, more than half of the facilities had efficiency scores below 0.50 and only a minority reached full efficiency. Similar variability has been reported for VMMC services in Kenya, Rwanda, South Africa and Zambia, where efficiency scores varied widely between facilities and many sites did not reach the empirical efficiency frontier^{10,11,13}. In Nyanza, Kenya, for example, mean variable returns to scale efficiency remained around 0.84 to 0.89 despite scale up efforts, showing that a substantial share of inputs did not translate into higher output¹⁰. Broader health system studies in Asia and Africa also show that most facilities and health systems can increase outputs using current resources if efficiency improves^{12,15-17}. In Zambia, district level analysis of child health services found average technical efficiency of about 62 percent, with most inefficiency linked to poor input use and management rather than inappropriate scale¹². These findings are consistent with the pattern seen in the present VMMC analysis.

The gap between efficiency scores under constant and variable returns to scale in this study helps separate problems of management from problems of scale. Constant returns to scale scores, which mix both effects, were lower than variable returns to scale scores. At the same time, scale efficiency was high for most facilities, suggesting that their size is generally appropriate and that pure managerial inefficiency is the larger problem. Similar conclusions have been drawn from other Zambian work. An efficiency study of child health services found that about two thirds of overall technical inefficiency could be attributed to district managers not using the right mix of inputs and not following good management practices, rather than to wrong scale of operation¹². Studies of VMMC and other HIV services across Kenya, Rwanda, South Africa and Zambia also report that variation in performance is more strongly linked to how services are organised, staffed and managed than to levels of spending alone^{11,13,18}. Together, this suggests that improving how staff, equipment and outreach time are used is likely to bring greater gains than simply increasing budgets or expanding physical capacity.

The benchmarking analysis in this study identified a small set of best performing facilities that form the efficiency frontier. One facility in particular served as the main peer for many under performing sites. This pattern, where a few facilities repeatedly appear as references for others, has also been observed in VMMC scale up in Kenya, where a limited number of high performing sites dominated the peer sets for inefficient facilities¹⁰. In that setting, these benchmark facilities were distinguished by better use of staff time, shorter procedure times and smoother client flow¹⁰. Similar insights have emerged in wider DEA work, where benchmarking is used to identify realistic performance targets drawn from comparable units in the same system^{12,15,16}. Because the efficient facilities in the present study operate under the same national policies and funding arrangements as less efficient sites, their performance can be considered an attainable standard. Programme managers can therefore use these frontier facilities as practical models for peer learning, targeted supervision, exchange visits and sharing of simple management tools, such as client flow protocols and staff task allocation. Evidence from continuous quality improvement efforts in South African VMMC programmes shows that coaching, clear guidelines

and on site mentoring can improve service processes and overall quality, supporting the view that structured learning from better performers is a promising strategy¹⁹.

It is also important to understand that low measured efficiency does not always reflect poor management alone. Facilities may have adequate staff and capacity but still perform few circumcisions because of weak demand in their catchment areas. Several studies in sub Saharan Africa have shown that VMMC uptake depends heavily on social norms, community awareness, age specific preferences and geographic access^{8,20–23}. A large costing study across six African countries reported that many sites had not yet reached client volumes needed to fully exploit economies of scale, and highlighted the need for stronger demand creation to increase throughput and reduce unit costs²⁴. A related analysis showed that mobile or campaign style services with strong outreach could attract far more clients at lower average cost than static sites, again underlining the role of demand side factors^{20,24}. In Zambia and other countries, qualitative work with VMMC clients has documented repeated failed attempts to get circumcised because of service side barriers such as clinic schedules or waiting times, but also highlighted fears, misinformation and social pressures that delay decisions to seek services²³. Mapping studies further show large subnational variation in male circumcision coverage, with some districts far behind national targets despite years of programme activity²¹. These findings suggest that some facilities in the present study may appear technically inefficient because not enough men are coming forward, rather than because staff are unwilling or unable to work productively.

The policy message that follows is that improving efficiency in Zambia's VMMC programme requires action on both the supply and demand sides. On the supply side, there is clear room to reorganise services using lessons from higher performing local facilities and from multi country analyses that link lower unit costs to higher volumes, task sharing, and integration with other HIV services^{13,24,25}. On the demand side, facilities with persistently low output despite adequate capacity are likely to benefit more from focused community engagement, adolescent friendly services and tailored communication than from internal reallocation of staff. Reviews of adolescent sexual and reproductive health services and VMMC uptake show that engaging parents and community leaders, protecting privacy and addressing fears about pain and traditional practices can make services more attractive to young men^{8,22}. Combining these demand generation efforts with improvements in service organisation and quality is likely to yield the greatest gains in both coverage and efficiency.

Study Limitations

This study has several limitations that should be considered when interpreting the findings. First, the analysis relied on secondary data from the Global Fund TB/HIV 2023 survey, which was collected for programme monitoring purposes rather than efficiency analysis. This limited the variables available for inclusion in the DEA model. Important inputs such as surgical kit supply, equipment availability, staff skill mix, and financial expenditure were not captured and could not be included. Their omission may have introduced some bias in the efficiency estimates.

Second, only 67 of 183 surveyed facilities had complete data on all DEA variables and were therefore included in the analysis. Facilities excluded due to missing data may differ systematically from those included, which could affect the generalisability of findings. Third, DEA assumes all deviation from the frontier reflects inefficiency and does not account for measurement error. Given the reliance on routine programme data, some inaccuracies in recording cannot be excluded.

Despite these limitations, the study provides the first facility-level DEA analysis of VMMC technical efficiency in Zambia and generates findings that are directly relevant to programme planning. Future research should incorporate longitudinal data to enable productivity analysis over time, include financial and quality-of-care variables where available, and apply second-stage regression to identify facility-level and contextual determinants of efficiency scores.

Conclusions

VMMC service delivery in Zambia shows considerable room for improvement, as many facilities are not making the best use of the resources already available to them. Despite this, most facilities appear to be operating at an appropriate size, suggesting that the main challenges are related to service organisation, management practices, and how staff and outreach activities are coordinated rather than shortages in infrastructure or facility capacity. This means that important improvements in service delivery could be achieved without major additional investment by strengthening operational efficiency and adopting successful practices from better-performing facilities.

The study also identified a small group of high-performing facilities that demonstrate that efficient VMMC service delivery is achievable within the Zambian health system. Learning from these facilities through peer mentorship, exchange visits, and sharing of practical management approaches could help improve performance across other sites. As Zambia increasingly relies on domestic resources to support its HIV response, improving efficiency will become even more important. The findings further show that Data Envelopment Analysis is a valuable tool for identifying performance gaps and guiding evidence-based resource allocation in VMMC programmes.

Abbreviations

ART
Antiretroviral Therapy
BCC
Banker, Charnes and Cooper Model
CBV
Community-Based Volunteer
CCR
Charnes, Cooper and Rhodes Model
CRS

Constant Returns to Scale
DEA
Data Envelopment Analysis
DMU
Decision-Making Unit
HIV
Human Immunodeficiency Virus
IQR
Interquartile Range
MOH
Ministry of Health
NGO
Non-Governmental Organisation
PEPFAR
President's Emergency Plan for AIDS Relief
PTE
Pure Technical Efficiency
SD
Standard Deviation
SE
Scale Efficiency
UNAIDS
Joint United Nations Programme on HIV/AIDS
UNZABREC
University of Zambia Biomedical Research Ethics Committee
VMC
Voluntary Medical Male Circumcision
VRS
Variable Returns to Scale
WHO
World Health Organization
ZAMPHIA
Zambia Population-based HIV Impact Assessment
ZDHS
Zambia Demographic and Health Survey

Declarations

Ethics Approval and Consent to Participate

Ethical approval for this study was obtained from the University of Zambia Biomedical Research Ethics Committee (UNZABREC). Administrative permission to access and use the Global Fund TB/HIV 2023 dataset was obtained from the Zambia Ministry of Health and the relevant data custodians. The study relied exclusively on anonymized secondary data with no direct participant contact. No personally identifiable information was accessed during or after data collection. In accordance with institutional ethical guidelines and the Declaration of Helsinki, a waiver of informed consent was granted by UNZABREC because the study involved secondary analysis of pre-existing de-identified data.

Consent for Publication

Not applicable. The study used anonymized secondary programmatic data and did not include identifiable individual information.

Availability of Data and Materials

The datasets analysed during the current study are not publicly available because they were obtained through institutional permission from the Zambia Ministry of Health and the Global Fund TB/HIV programme. Data may be made available from the corresponding author upon reasonable request and with permission from the relevant data custodians.

Competing Interests

The authors declare that they have no competing interests.

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This study received no external funding. The research was conducted as part of academic requirements at the University of Zambia. The funders and data custodians had no role in the design of the study, analysis, interpretation of findings, manuscript preparation, or the decision to publish.

Authors' Contributions

NH conceptualized the study, conducted the data analysis, interpreted the findings, and drafted the manuscript. WM, CM, and MC contributed to study supervision, interpretation of results, and critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

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