

Epidemiology of antimicrobial use in Malawi: a cross-sectional study using World Health Organisation core antimicrobial use indicators in faith-based health facilities

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Abstract

Background: Antimicrobial resistance (AMR) is a major public health threat globally, with a disproportionate burden in sub-Saharan Africa. Faith-based health facilities provide essential healthcare services to underserved populations, yet data on antimicrobial use in these settings remain limited.

Aim: To assess antimicrobial use in Christian Health Association of Malawi health facilities using the World Health Organisation core medicine use indicators.

Materials and Methods: A multicentre cross-sectional study was conducted in 29 CHAM health facilities across Malawi between January 2024 and June 2025. Data were collected from facility personnel, inpatient prescriptions, and patient interviews and analysed using descriptive and inferential statistics.

Results: Average availability of key antimicrobials was 33.1% (95% CI: 29.7–36.4), while customised formularies were available in 64.3% of health facilities. Among 660 prescriptions analysed, 90.3% contained an antimicrobial agent, but only 33.2% adhered to standard treatment guidelines and 43.6% were prescribed using full generic names. Facilities with pharmacy professionals were more likely to have a facility-specific formulary (84.6% vs. 46.7%, $p = 0.037$).

Conclusion: Antimicrobial stewardship gaps remain substantial in faith-based health facilities in Malawi and across sub-Saharan Africa, highlighting the need for targeted stewardship programmes in faith-based health facilities.

Key words: Antimicrobial resistance, faith-based healthcare, WHO antimicrobial use indicators, sub-Saharan Africa

Introduction

Antimicrobial resistance (AMR) occurs when microorganisms develop the ability to survive exposure to antimicrobial agents that would normally inhibit or eliminate them at established therapeutic doses. AMR has emerged as one of the greatest threats to global public health, compromising the prevention and treatment of infectious diseases and threatening decades of progress in modern medicine. The World Health Organisation (WHO) estimated that 1.27 million deaths were directly attributed to AMR and that 4.95 million deaths were associated with AMR globally in 2019 (1, 2). Beyond its impact on morbidity and mortality, AMR imposes substantial economic consequences on healthcare systems and societies. Studies have shown that antimicrobial resistant infections increase hospital costs by an estimated USD 29,289 per patient and contribute to an estimated global healthcare expenditure exceeding USD 693 billion annually (3, 4). Consequently, AMR is recognised as both a public health emergency and a major threat to sustainable healthcare financing in the world.

The burden of AMR is disproportionately concentrated in low- and middle-income countries (LMICs), particularly those in sub-Saharan Africa (SSA), where infectious diseases remain highly prevalent and antimicrobial medicines are indispensable for clinical care (5). In 2019, an estimated 250,000 deaths were directly attributed to AMR, and 1.05 million deaths were associated with AMR in SSA (6). Lower respiratory tract infection remains among the leading causes of mortality and morbidity in the region, with pathogens such as *Streptococcus pneumoniae*, *Klebsiella pneumoniae*, *Escherichia coli*, and *Staphylococcus aureus* contributing substantially to the disease burden (6).

Malawi, a SSA country, is not spared from the burden of AMR. In 2021, AMR was directly attributed to 2,520 deaths and was associated with 13,837 deaths nationally (7). Additionally, several studies have reported increasing resistance among clinically important pathogens in the country, signalling a worsening AMR landscape and posing significant threats to effective infection management (8-11). Recognising the magnitude of the challenge, Malawi joined other World Health Assembly member states in adopting the updated WHO Global Action Plan on AMR 2026-2036, which identifies optimisation of antimicrobial use as a central pillar for reducing the emergence and spread of resistance (12). Achieving this objective requires a coordinated One Health approach across the human, animal, and environmental sectors, as fragmented implementation may undermine national and global efforts to contain AMR.

Healthcare delivery in Malawi is provided through both public and private sectors, with the latter comprising for-profit providers, non-government organisations and faith-based healthcare institutions. Faith-based health facilities constitute an integral component of health service provision throughout SSA and frequently serve underserved and rural populations. In Malawi, the Christian Health Association of Malawi (CHAM) is the largest faith-based healthcare provider, operating 194 health facilities across 27 of the country's 28 districts and contributing approximately 37% of national healthcare services (13). Importantly, CHAM facilities serve nearly 75% of remote rural and hard-to-reach populations (14), thereby playing a critical role in achieving the recommended 5–8 km geographical accessibility target for healthcare services. Through its commitment to national health policies and service level agreements with the Government of Malawi, CHAM subsidises maternal, neonatal and child health services to improve access to care. However, resource constraints, supply chain challenges, and parallel health systems may hinder implementation of antimicrobial stewardship (AMS) and antimicrobial use monitoring. Understanding

antimicrobial use practices within faith-based health facilities is therefore essential to ensure that national AMR strategies effectively reach all healthcare providers and populations.

Assessment of antimicrobial use is a fundamental component of AMS programmes and a key strategy for combating AMR. To facilitate standardised monitoring, WHO developed drug use indicators, revised in 2006, that evaluate healthcare facility characteristics, prescribing practices, and patient care influencing antimicrobial use (15). Numerous studies globally have assessed antimicrobial use using WHO indicators, and other antimicrobial stewardship metrics; however, most have focused on public healthcare facilities, outpatient settings, specific infectious diseases, or selected prescribing indicators (16-33). Evidence evaluating antimicrobial use comprehensively across healthcare facility, prescribing, and patient-care indicators remains limited, particularly in faith-based healthcare settings. Furthermore, data on antimicrobial use patterns in faith-based health facilities using WHO antimicrobial use indicators are scarce globally, particularly in sub-Saharan Africa, including Malawi.

This study assessed antimicrobial use in CHAM health facilities in Malawi using WHO antimicrobial use indicators. By generating evidence from under-represented but strategically important healthcare sectors, this study provides a case example for faith-based healthcare systems in SSA and contributes to strengthening AMS efforts under Malawi's national AMR programme and action plan.

Material and methods

Full details of the study design, sampling procedure, and data collection methods are described in the published study protocol (34); key elements are summarised below.

Study design and setting

This was a multi-centre cross-sectional study conducted in 29 CHAM health facilities across 13 of the 27 districts where CHAM health facilities are located, covering all three geographical regions of Malawi (Northern, Central and Southern) **S1 Table**. The study assessed antimicrobial use using three WHO antimicrobial use core indicators: health facility, prescribing and patient care indicators (15) **Table 1**. Minimum sample sizes for health facility and prescribing indicators followed WHO recommendations for assessing antimicrobial use in health facilities (15), while the sample size for patient-care indicators was calculated to achieve a pre-specified level of precision (95% CI, $\pm 5\%$) described in the protocol (34). The study was conducted between January 2024 and June 2025.

Table 1: WHO indicators for assessing antimicrobial use in health facilities.

Core indicators	Specific indicators	Optimal value
Health facility	i. % of availability of standard treatment guidelines (STG)	100
	ii. % of availability of health facility's own formulary	100
	iii. Average number of antimicrobials on formulary	-
	iv. % of availability of key antimicrobials	100
	v. Average stock-out days of key antimicrobials	0

	vi. Average antimicrobial expenditure	-
Prescription	i. % of hospitalisation with antimicrobial prescribed	20.0–26.8
	ii. Average cost of antimicrobials (USD)	-
	iii. Average duration of antimicrobial treatment (days)	-
	iv. % of antimicrobials prescribed consistently with STGs.	100
	v. % antimicrobials prescribed by generic name	100
Patient	i. % of patients who received all prescribed antimicrobials	100
	ii. % of patients receiving medicine within acceptable dispensing time of ≥ 1.5 minutes (90 seconds)	100
	iii. % of patients with knowledge of correct dose	100
	iv. % of medicines adequately labelled	100

161 WHO indicators assessed in this study. Optimal value represents WHO recommended
162 targets for antimicrobial use in health facilities. Indicators without established WHO targets
163 are reported descriptively. Adapted from WHO methodology for investigating antimicrobial
164 use in health facilities.

165

166 ***Study participants***

167 For health facility indicators, randomly selected health facilities that were operational
168 on the day of data collection were included. Health facilities which were temporarily closed
169 because of community-related disputes or lacked admitted patients at the time of data
170 collection, a common occurrence in some CHAM facilities because of their cost-recovery

health care service model were replaced through simple random sampling **S1 Table**. Respondents for the health facility indicators were health facility in-charges, including medical directors (medical doctors), clinical in-charges (clinical officers with a diploma in clinical medicine or clinical assistants with a certificate in clinical medicine), nurses, human resource managers, and public administrators (including Catholic nuns and priests). As for prescribing and patient care indicators, inpatient prescriptions with the corresponding patient available for interview were included, while illegible, incomplete, duplicate, or invalid prescriptions were excluded. Children under five years of age were excluded to improve the comparability of prescribing and patient care indicators, as antimicrobial prescribing practices, formulations, and dosing in this age group differ substantially from those in older children and adults.

Data collection

Data were collected using KoboToolbox v2021.2.4 (35) through standardised electronic questionnaires. Close monitoring ensured data quality and consistency throughout data collection. Each participating health facility appointed a coordinator who received standardised training on prescribing and patient care data collection. Standardised coordinator training and the use of a structured KoboToolBox data-capture form were intended to limit measurement and data-entry bias, while random replacement of temporarily closed or non-functional facilities (described above) was intended to limit selection bias arising from facility substitution. Potential recall or social-desirability bias in patient-reported responses could not be independently verified against an external reference standard. As shown in **Fig 1**, data collection started with communication and courtesy visits to facility in-charges, followed by engagement with ward, pharmacy and data personnel. Data were collected between July 2024 and June 2025.

Fig 1. Data collection workflow for the study. Black arrows show communication pathways and movement of the data collection team, while blue arrows indicate data sources. Boxes represent study entities and circles represent data collected.

Health facility indicators

Health facility indicators data were collected from 29 randomly selected health facilities in **S1 Table**. Data were obtained through on-site visits or remotely. Clinical in-charges provided information on STGs, pharmacy in-charges provided formulary and antimicrobial availability data, and facility in-charges, accounts personnel, and data clerks provided expenditure, catchment population, and facility characteristic data.

Prescribing and patient care indicators

A total of 682 prescriptions were reviewed in accordance with WHO recommendations (15). The protocol specified a target of 22 health facilities, with approximately 30 prescriptions sampled per facility (660 prescriptions in total) (46). Of the 682 prescriptions reviewed, 670 were retained for the final analysis after excluding illegible, incomplete, duplicate, or invalid prescriptions (34). These 670 prescriptions formed the dataset for the prescribing indicators and were also used to assess patient care indicators because they contained all variables required for both assessments, replacing the initially planned sample of 303 participants for the patient care indicators. Data were collected from clinicians, nurses, pharmacy personnel, and patients **Fig 1**.

219 ***Ethical considerations***

220 The study was approved by College of Medicine Research Ethics Committee
 221 (COMREC; now Kamuzu University of Health Science Research Ethics Committee
 222 [KUREC]) under approval number P.04/24-0651 in May 2024. The approval to conduct the
 223 study in CHAM health facilities was subsequently obtained from the CHAM Secretariat
 224 management. The study was conducted in accordance with the Declaration of Helsinki. Oral
 225 informed consent was obtained from all participants prior to data collection, with assent
 226 obtained for participants younger than 18 years. Participants were informed that refusal to
 227 participate or withdrawal from the study would not affect the healthcare services they
 228 received.

229

230 ***Data analysis***

231 Data captured using KoboToolBox were downloaded into Microsoft Excel 2016,
 232 checked for missing entries, cleaned, and coded. A clinician on the study team created five
 233 additional variables: receipt of antimicrobials, number of prescribed antimicrobials per
 234 participant, treatment cost based on prevailing Malawian market prices (United States
 235 Dollars, USD) (36), treatment duration, and adherence to STGs. Statistical analysis was
 236 performed using Stata SE version 14 (37). Descriptive statistics were used to summarise the
 237 data, with continuous variables presented as mean (95% confidence interval, CI) or median
 238 (interquartile range, IQR) and categorical variables as frequencies and percentages. To
 239 assess differences across levels of care, outcomes were stratified by CHAM facility type: full-
 240 fledged hospitals (secondary healthcare facilities), community hospitals (intermediate-level
 241 facilities), and health centres (primary healthcare facilities).

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Associations between categorical variables were assessed using Pearson's chi-square test, differences in means across facility types were assessed using analysis of variance (ANOVA) or the t-test, as appropriate. Correlations between continuous or ordinal variables were assessed using Spearman's rank correlation (ρ), using a significance level (α) of 0.05. All reported tests were unadjusted bivariate analyses; no multivariable adjustment for potential confounders was performed. Analyses used all available records for each variable (available-case analysis); no imputation was performed for missing data, and denominators are reported alongside each estimate to indicate the amount of missing data. Facilities were sampled as clusters containing multiple prescriptions and patients, but standard errors were not adjusted for facility-level clustering; observations were treated as independent. No additional sensitivity analyses were performed.

Results

Baseline characteristics of the study health facilities, prescriptions and patients.

A total of 29 CHAM health facilities and 670 prescribing and patient-care records were included in the analysis. Most facilities were health centres (19/29, 65.2%), and consistent with CHAM's mission of providing healthcare services to underserved populations, nearly half were in hard-to-reach areas (13/28, 46.3%) **Table 2**. Among patients, 396 (59.1%) were female, while one participant preferred not to disclose their sex.

Table 2: Baseline characteristics of the study

Core indicators	Characteristics	Output
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Facility indicators	<i>Facility type</i>	<i>n=29 (%)</i>
	Health centre	19 (65.2)
	Community hospital	5 (17.2)
	Full-fledged hospitals	5 (17.2)
	<i>Country region</i>	<i>n=29 (%)</i>
	Northern	9 (31.0)
	Central	13 (44.8)
	Southern	7 (24.1)
	<i>Reachability</i>	<i>n=28 (%)</i>
	Tarmac to facility	3 (10.7)
Prescribing and Patient indicators	Close to tarmac road (1km)	12 (42.9)
	Very hard-to-reach	13 (46.3)
	<i>Age</i>	<i>n=670 (%)</i>
	6–17 years (children)	192 (28.7)
	18–70 years (adults)	422 (63.0)
	≥71 years (elderly)	56 (8.4)
	<i>Sex</i>	<i>n=670 (%)</i>
	Male	273 (40.8)
	Female	396 (59.1)
	Prefer not to say	1 (0.2)
	<i>Prescriber</i>	<i>n=587 (%)</i>
	Specialist doctor	1 (0.2)
	General doctor	11 (1.9)
	Clinical technician (diploma)	465 (79.2)
	Clinical assistant (certificate)	22 (3.8)
	Nurse (degree)	83 (14.1)
	Nurse (diploma)	4 (0.7)
	Others (unspecified)	1 (0.2)
	<i>Dispenser</i>	<i>n=586 (%)</i>
	Pharmacist (degree)	16 (2.7)
	Pharmacy technician (diploma)	210 (35.8)
	Pharmacy assistant (certificate)	138 (23.6)
	Nurse	154 (26.3)
	Clinician	2 (0.4)
	Pharm technician and nurse	55 (9.4)
	Others (attendants/mixed)	11 (1.9)

Baseline characteristics of participating CHAM health facilities, patients, prescribers, and dispensers. Percentages were calculated using available data for each variable and may not total 100% because of rounding off or missing data.

Facility indicators

All 29 health facilities responded to the availability of STGs, with 24 (85.7%) reporting availability. Of the 28 facilities that responded to the question on having a facility-specific formulary, 18 (64.3%) had one available **Table 3**. The mean availability of key antimicrobials was 33.1% (95% CI: 29.7–36.4), while the average stock-out duration was 1.4 days (95% CI: 0.77–2.12). Antimicrobials accounted for a median of 40.0% (IQR: 25.3–57.1) of the health facility medicine procurement expenditure.

Table 3: Health facility indicators assessment

Health facility indicators	Outcome	Optimal value
Availability of STG (n=29)	24 (85.7%)	100
Availability of the facility's own formulary (n=28)	18 (64.3%)	100
Average number of antimicrobials on formulary	30.7	-
Availability of key antimicrobials, % (n=28)	33.1 (95% CI: 29.7–36.4)	100
Average key antimicrobials stock-out days (n=27)	1.4 (95% CI: 0.77–2.12)	0
Median antimicrobial expenditure, % (n=25) ^a	40.0 (IQR: 25.3–57.1)	-

Health facilities indicators where percentages were calculated using available responses for each variable. Denominators may vary because of missing data.

^aExpenditure was converted from Malawi Kwacha to United States Dollars (USD) using the prevailing Reserve Bank of Malawi exchange rate in June 2025 (36).

The presence of a pharmacy professional at a health facility was significantly associated with the availability of a facility-customised formulary ($\chi^2 = 4.37$, $p = 0.037$). Facilities with a pharmacy professional were more likely to have their own formulary than facilities without a pharmacy professional (84.6% vs. 46.7%) **Fig 2**. We found no association between facility type and the availability of key antimicrobials ($F[2,26] = 1.65$, $p = 0.211$), the presence of a pharmacy professional and the availability of key antimicrobials at health facilities ($t = 1.19$, $p = 0.245$) or the facility reachability and availability of key antimicrobials ($F[2,25] = 0.12$, $p = 0.892$).

Fig 2. Association between the presence of pharmacy professionals and the availability of an in-house formulary. Pearson's chi-square test was used to assess the association, with an asterisk (*) indicating a statistically significant association ($p < 0.05$).

Prescribing and patient care indicators

For prescribing indicators, 219 (33.2%) antimicrobials were prescribed in accordance with STG, with an average treatment duration of 4.7 days **Table 4**. The average antimicrobial treatment cost was USD 9.1, while generic prescribing was 43.6%; most prescriptions (1,205; 53.9%) used abbreviated generic names **S2 Fig**. For patient care indicators, 568 (98.1%) patients received all prescribed antimicrobials. Responses were available for 45 and 47 patients on knowledge of the correct dose and medicine labelling, respectively. Of these, 38 (84.4%) correctly stated the dose of their treatment, while only 17 (36.2%) received adequately labelled medicines.

Table 4: Assessment of prescribing and patient care indicators

Prescribing and patient care indicators	Outcome	Optimal value
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<i>Prescribing indicators</i>		
Antimicrobials prescribed consistently with STG (% , n=660)	33.2	100
Hospitalisation with antimicrobial prescribed (% , n=660)	90.3	20.0–26.8
Average cost of antimicrobials (USD, n=660) ^a	9.1	-
Average duration of antimicrobial treatment (days, n=598)	4.7	-
Antimicrobials prescribed by generic name (% , n=2237) ^b	43.6	100
<i>Patient care indicators</i>		
Percentage of patients who received all prescribed antimicrobials (% , n=579)	98.1	100
Percentage of patients receiving medicines within acceptable dispensing time of ≥ 1.5 minutes or 90 seconds (% , n=578)	99.1	100
Percentage of patients with knowledge of correct dose (% , n=45)	84.4	100
Percentage of medicines adequately labelled (% , n=47)	36.2	100

305 Prescribing and patient care indicators where percentages were calculated using available
306 responses for each variable. Denominators may vary because of missing data.

307 ^aCost was converted from Malawi Kwacha to United States Dollars (USD) using the
308 prevailing Reserve Bank of Malawi exchange rate in June 2025 (36).

309 ^bThe denominator for generic prescribing was 2,237 antimicrobials, as some patients
310 received more than one antimicrobial.

311

312 Patients attending community hospitals were significantly more likely to receive
313 antimicrobial treatment than those attending health centres or full-fledged hospitals ($\chi^2 =$
314 13.24, $p = 0.001$) **Fig 3**. There was also a significant association between patient age and
315 receipt of an antimicrobial prescription ($\chi^2 = 29.95$, $p < 0.001$), with the likelihood of receiving
316 an antimicrobial increasing with age **Fig 4**. The number of prescribed antimicrobials was

positively correlated with antimicrobial treatment cost (Spearman's $\rho = 0.776$, $p < 0.001$)

S2 Fig. Prescriber professional level did not significantly influence antimicrobial prescribing ($F(6,573) = 1.75$, $p = 0.107$).

Fig 3. Association between the facility type and patients receiving antimicrobial treatment. Pearson's chi-square test was used to assess the association, with an asterisk (*) indicating a statistically significant association ($p < 0.05$).

Fig 4. Association between patient age and receipt of an antimicrobial prescription. Asterisks (*) indicate statistically significant associations based on Pearson's chi-square test ($p < 0.05$).

Discussion

This study provides the very first comprehensive assessment of antimicrobial use using the three WHO core indicators within faith-based health facilities in a sub-Saharan African country. The findings demonstrate significant gaps in AMS implementation across CHAM health facilities despite their major contribution to healthcare delivery in Malawi, particularly for rural and underserved populations, who comprise more than 80% of the country's population (38). At the health facility level, availability of STG (85.7%) and facility customised formularies (64.3%) remained below the WHO target of 100%, suggesting incomplete stewardship infrastructure. Similar gaps have been reported in hospitals in Zambia (31, 39). Importantly, health facilities with pharmacy professionals were significantly more likely to possess facility-specific formularies, reinforcing evidence that pharmacists play a critical role in AMS through formulary management, guideline implementation, clinical audit, and optimisation of prescribing practices (40, 41). However, the most concerning

health facility finding was the low availability of key antimicrobials (33.1%), which was considerably lower than values reported from Palestinian hospitals and other healthcare settings (26). Although average stock-out duration was relatively short, poor antimicrobial availability may compel prescribers to select medicines based on availability rather than clinical appropriateness, potentially increasing inappropriate use of broad-spectrum agents and accelerating AMR. Furthermore, antimicrobials accounted for approximately 40% of medicine procurement expenditure, highlighting their substantial financial burden on faith-based healthcare systems. Similar observations have been reported globally, where antimicrobial procurement represents a major component of healthcare expenditure and contributes substantially to the economic burden associated with AMR (2, 42). These findings collectively suggest that strengthening pharmaceutical supply systems and pharmacy workforce capacity should be central components of antimicrobial stewardship programmes within faith-based health facilities.

The prescribing indicators revealed substantial departures from WHO recommendations, suggesting opportunities for stewardship improvement. The prevalence of antimicrobial prescribing among hospitalised patients was 90.3%, which greatly exceeds the WHO optimal range of 20.0–26.8% and is considerably higher than reports from Zambia (59.0%), Afghanistan (49.1%), Tanzania (26.1%), Saudi Arabia (26.5%), and Ghana (18–36%) (21–23, 25, 27). This high prevalence likely reflects the substantial burden of infectious diseases, reliance on empirical treatment, limited access to microbiological diagnostics, and the inpatient nature of the study population. Nevertheless, such extensive antimicrobial exposure creates substantial selective pressure for resistance development. Equally concerning was the low adherence to STGs, with only one-third of antimicrobial prescriptions consistent with recommended treatment protocols. Although this finding was slightly higher than that reported in Zambian hospitals (27%), it remains substantially below levels reported in facilities with more established AMS programmes (27, 43). Poor adherence may reflect

medicine availability constraints, limited access to updated treatment guidelines, inadequate stewardship oversight, and diagnostic uncertainty. Generic prescribing was also low at 43.6%, falling below values reported from Afghanistan, Ghana, Pakistan, and Yemen (20-22). However, more than half of prescriptions used abbreviated generic names, suggesting that generic prescribing itself was common, but documentation practices were suboptimal. While abbreviated names may improve efficiency, they increase the risk of medication errors, misinterpretation, and dispensing inaccuracies. The average antimicrobial treatment duration of 4.7 days is consistent with the increasing global shift towards shorter treatment courses where clinically appropriate, although future studies should evaluate indication-specific treatment durations to determine whether observed prescribing patterns align with evidence-based recommendations.

Patient care indicators presented a mixed picture. On one hand, almost all patients received their prescribed antimicrobials (98.1%), and nearly all medicines were dispensed within the WHO-recommended dispensing time (99.1%). These findings are encouraging and likely reflect the CHAM cost-recovery healthcare model, where medicines are procured and available before treatment is initiated. Unlike many public sector facilities affected by medicine shortages, patients attending CHAM health facilities may therefore have improved access to prescribed antimicrobials. However, the possibility that clinicians prescribe according to medicine availability rather than optimal therapeutic choice cannot be excluded, particularly given the limited availability of key antimicrobials identified in this study. This concern becomes even more important when interpreted alongside evidence from AMS literature showing that medicine shortages frequently alter prescribing behaviour and may increase use of inappropriate alternatives (44, 45). While access to prescribed antimicrobials was high, patient understanding of treatment and dispensing quality remained suboptimal. Only 84.4% of patients correctly understood their dosage instructions, and merely 36.2% received adequately labelled medicines. Similar deficiencies have been reported across

several low- and middle-income countries and are recognised contributors to poor adherence, medication errors, treatment failure, and inappropriate antimicrobial use (46-48). Strengthening pharmacy services, improving dispensing practices, implementing standardised labelling procedures, and enhancing patient counselling therefore represent important steps for improving both AMS and patient outcomes within faith-based healthcare settings.

The study also identified several factors associated with antimicrobial use. Patients attending community hospitals were significantly more likely to receive antimicrobials than those attending health centres or full-fledged hospitals, suggesting that facility-level characteristics, case mix, and prescribing cultures influence antimicrobial utilisation. Similarly, increasing age was associated with a higher likelihood of receiving antimicrobials, which is consistent with evidence showing greater infection burden, increased comorbidity, and more frequent healthcare contact among older patients (49, 50). In contrast, prescriber professional level did not significantly influence antimicrobial prescribing practices, suggesting that institutional factors may exert a stronger influence on prescribing behaviour than individual professional training alone. This observation aligns with stewardship literature demonstrating that prescribing behaviour is often shaped by organisational culture, medicine availability, treatment guidelines, supervision structures, and healthcare system constraints rather than professional cadre alone (51).

This study has several limitations. Its cross-sectional design limits causal inference, and findings from CHAM facilities may not be fully generalisable to public or private healthcare settings. Patient knowledge and medicine-labelling indicators were based on relatively few respondents because of missing data. The number of prescriptions analysed (670) differs from the number planned in the protocol (660) and the number reviewed (682);

although this discrepancy is reconciled in the Methods, any unmeasured difference between excluded and included prescriptions could introduce a degree of selection bias or imprecision not fully captured by the reported confidence intervals. All associations reported in this study (chi-square, ANOVA/t-test, Spearman's rho) are unadjusted bivariate estimates; because facilities were sampled as clusters of multiple prescriptions and patients, but clustering was not accounted for in the analysis, standard errors and confidence intervals may be underestimated and statistical significance overstated. Nevertheless, this study provides important evidence on AMS in faith-based health facilities in Malawi and, through its nationally representative geographical and facility-level coverage, offers findings that may inform AMS strengthening in similar faith-based healthcare settings across sub-Saharan Africa.

Conclusion

This study demonstrates that AMS challenges remain substantial within faith-based health facilities in Malawi, particularly in prescribing practices, guideline adherence, and antimicrobial availability. Given the important role of faith-based providers in healthcare delivery across sub-Saharan Africa, these findings highlight critical opportunities to strengthen antimicrobial use and support AMR containment. Future studies should evaluate the clinical appropriateness of antimicrobial prescribing using microbiological investigations, culture-guided therapy, antimicrobial resistance patterns, and patient outcomes to better inform stewardship interventions.

Author's contribution

All authors made substantial contributions to the conception, study design, data acquisition, analysis, interpretation, and execution of the study; participated in drafting, revising, or critically reviewing the manuscript; approved the final version for publication; agreed on the target journal; and accepted responsibility for all aspects of the work.

Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the study design, data collection, analysis, interpretation and presentation of results, or decision regarding dissemination of the findings.

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627

628 **Supporting information**

629 **S1 Fig. Classification of antimicrobial prescribing by naming convention.**

630 Denominators represent the total number of antimicrobials prescribed rather than the
631 number of patients, as some patients received more than one antimicrobial. Percentage
632 represents what the number represents out of overall medicines prescribed.

633 **S2 Fig. Correlation between the number of prescribed antimicrobials and**
634 **antimicrobial treatment cost.** Each point represents an individual patient prescription,
635 while the Locally Weighted Scatterplot Smoothing curve illustrating the overall trend.

636 **S1 Table: Health facilities, prescriptions and patients in the study.** The health facilities
637 included those replacing closed or not reachable health facilities. For each facility, number of
638 prescriptions is indicated.

639 **S2 Table: Health facilities dataset.** The header row of the Excel file contains the variable
640 names and definitions (key) for all analysed variables.

641 **S3 Table: Prescription and patient dataset.** The header row of the Excel file contains the
642 variable names and definitions (key) for all analysed variables.

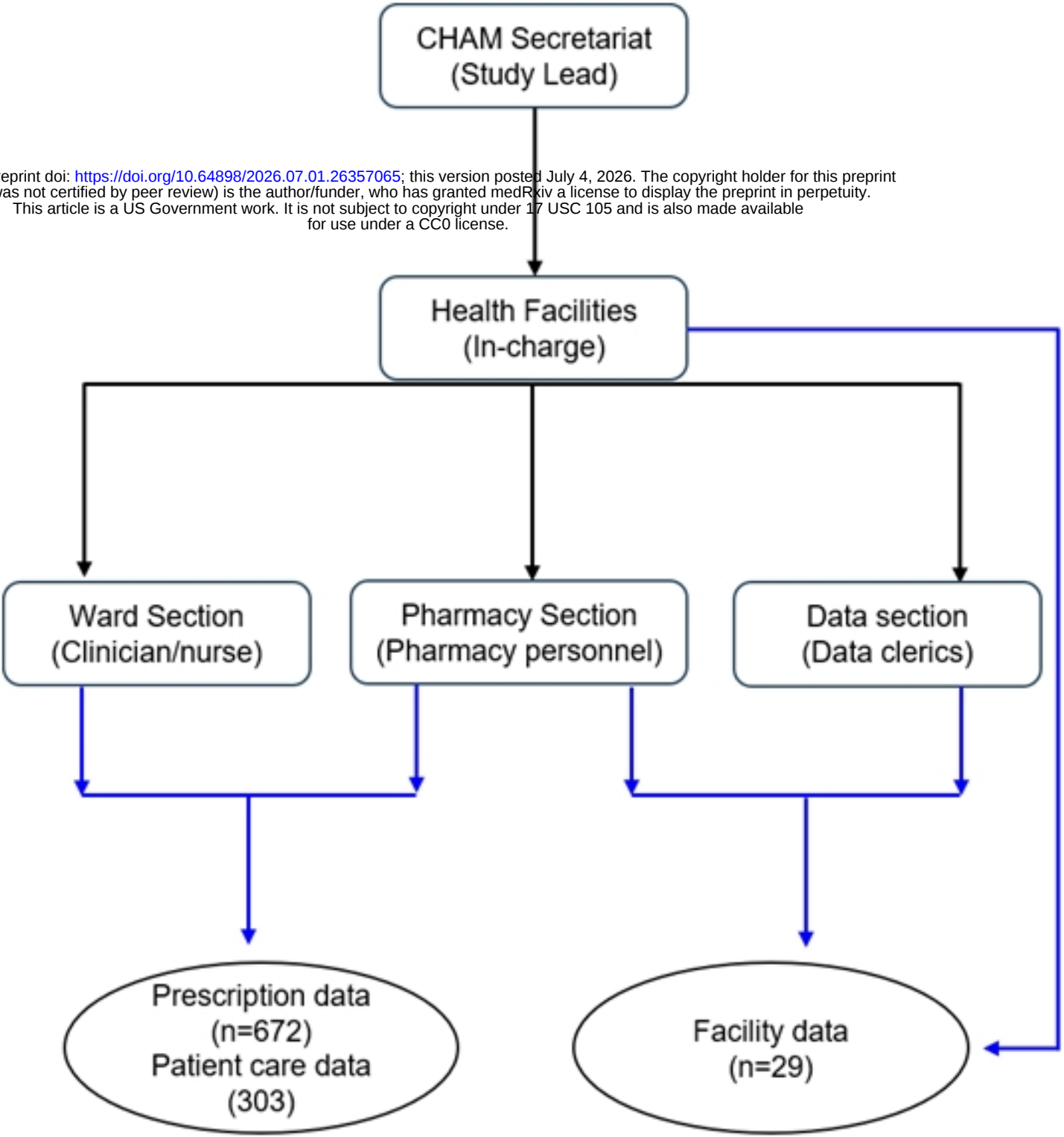


Figure 1: Data collection workflow for the study

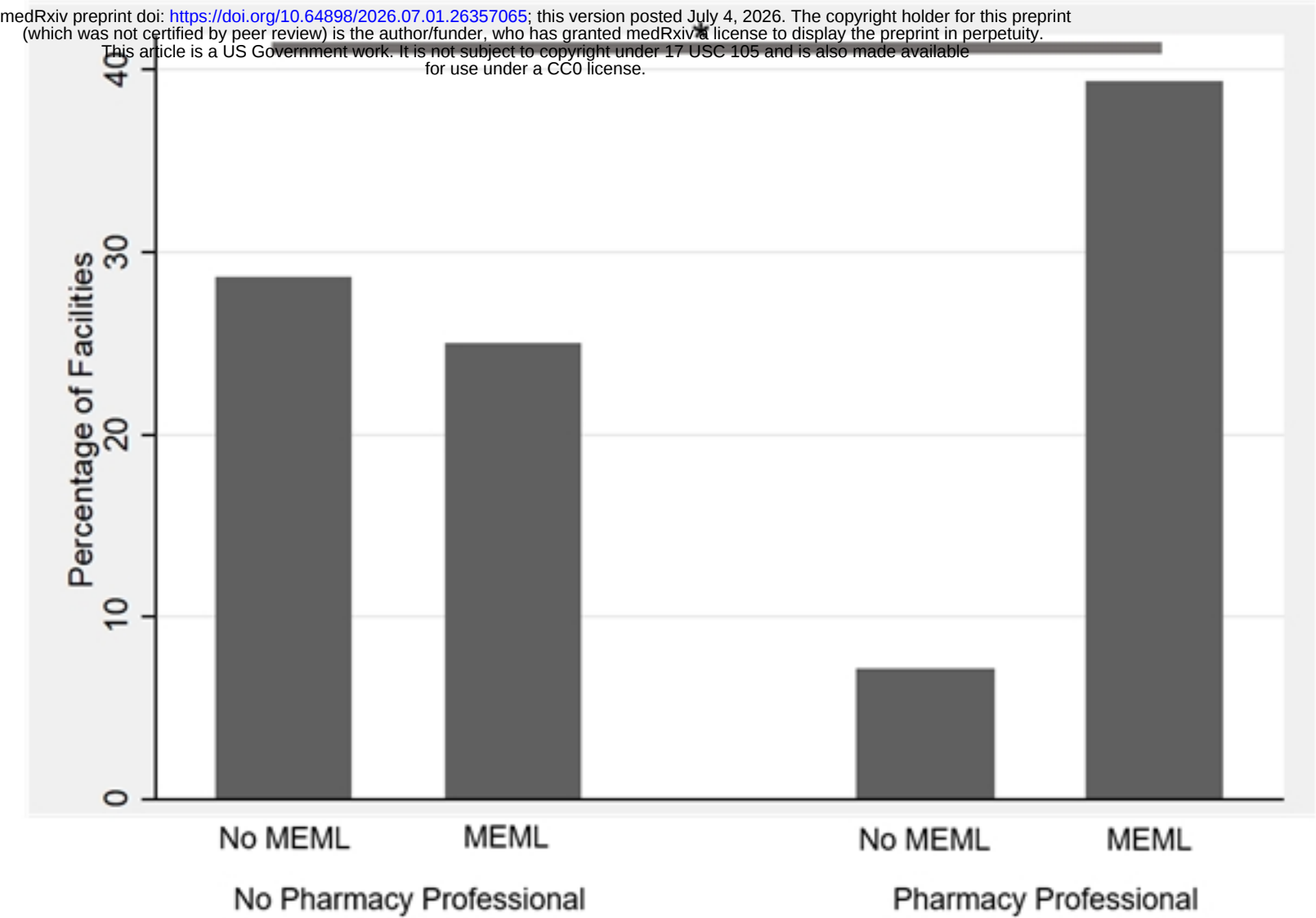


Figure 2: Association between pharmacy professional

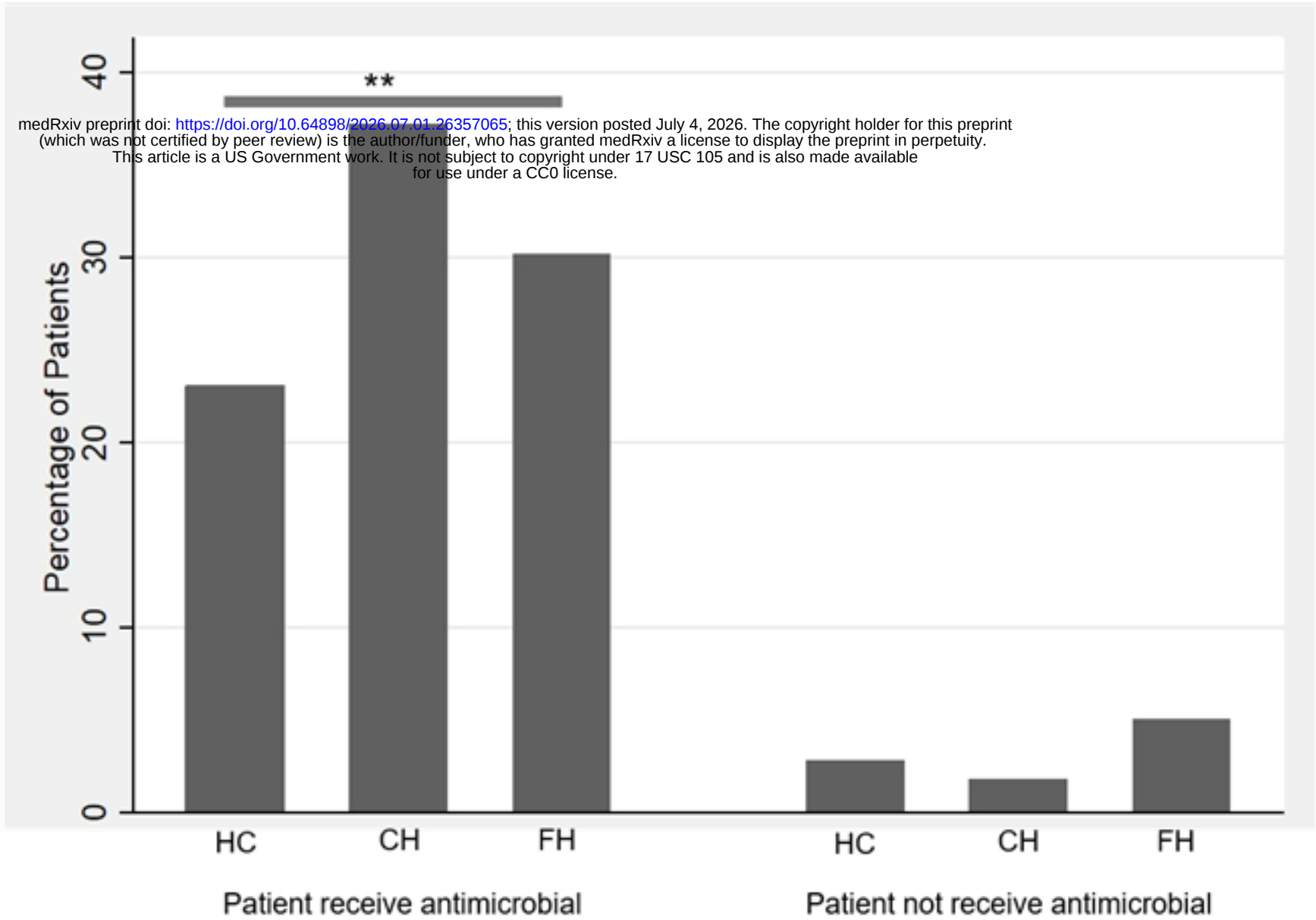


Figure 3: Association between the facility type and r

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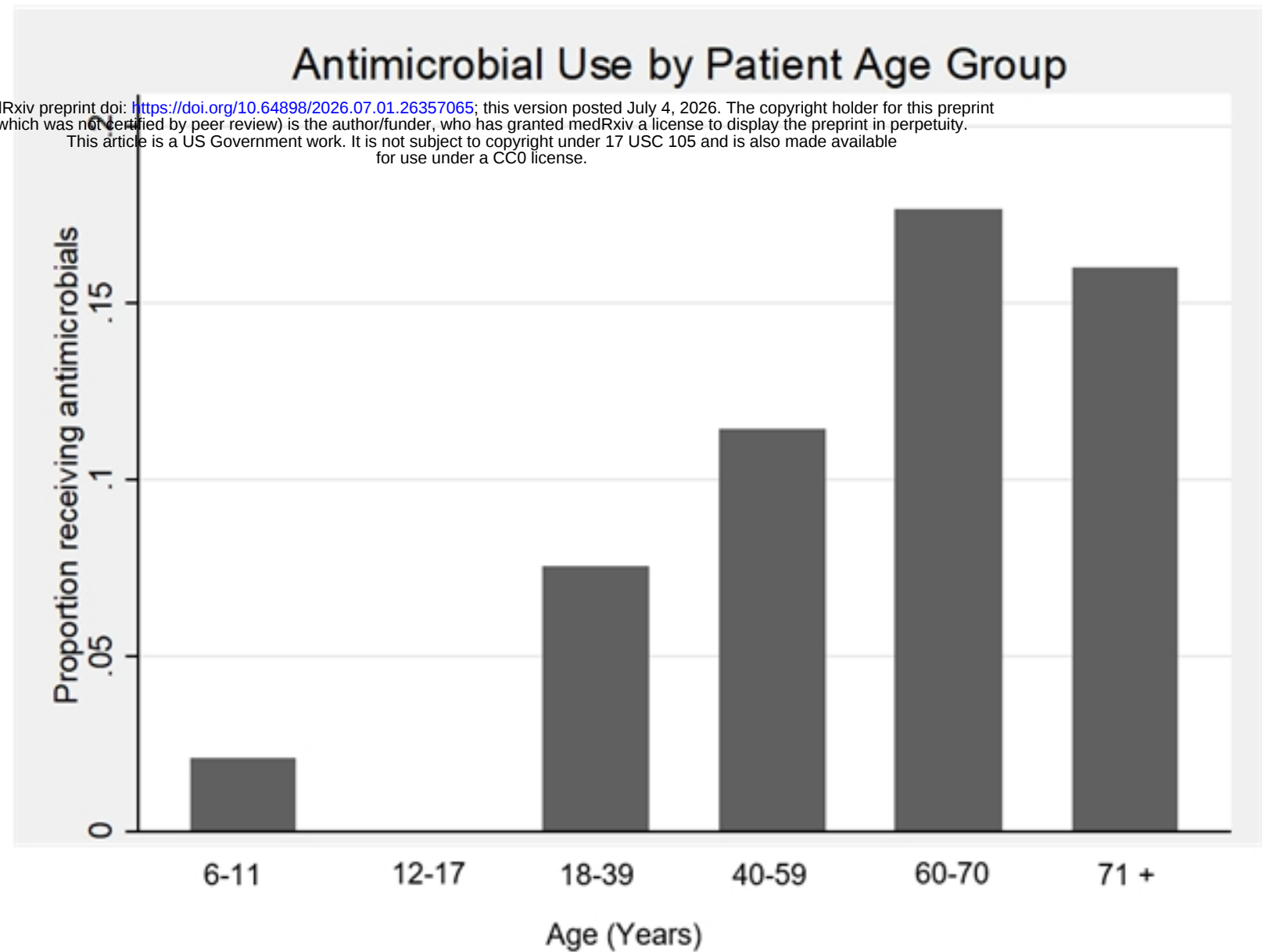


Figure 4: Association between patient age and receipt