

Stigma, awareness, and access: Social determinants of tuberculosis management in Sokoto state, Nigeria

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Abstract

Tuberculosis (TB) remains a major public health challenge in Nigeria, with Sokoto State bearing a significant burden. Social determinants, including stigma, poor awareness, and geographic accessibility, influence TB management outcomes. This study assessed social determinants affecting TB management in Sokoto State from 2020 to 2024. A descriptive cross-sectional design was employed, combining quantitative and qualitative methods. The study involved 200 respondents comprising health workers (40.0%), TB patients (27.5%), and public health officers (32.5%). Data were collected using structured questionnaires, patient record reviews, and key informant interviews. The Health Belief Model and Andersen's Health Care Utilization Model served as theoretical frameworks. Stigma/discrimination (36.0%) was the most significant barrier, followed by poor awareness/health education (30.0%). Long distance to treatment centers (12.5%), poor patient follow-up (7.5%), and drug stock-outs (9.0%) were also identified. Most respondents were male (59.0%), with 32.5% having no formal education. Treatment success rate was 80.0%, below the 85% WHO target. Concurrent research documented a "perception gap" where only 22.7% of caregivers perceived malnutrition as a problem despite 83.3% underweight prevalence. Additionally, 73.3% of households consume ≤4 food groups daily, 75.3% of caregivers have secondary education or less, 45.3% live in extreme poverty, and 65.3% live >5 km from health facilities. Social determinants, particularly stigma and poor awareness, significantly impede TB control in Sokoto State. Addressing these barriers through multi-level interventions, community awareness campaigns, engagement of religious/traditional leaders, peer support programs, and integration of TB services into general health services is critical to improving TB outcomes.

Keywords: Tuberculosis; Stigma; Awareness; Social Determinants; Health Belief Model; Andersen's Model; Sokoto State; Nigeria

1. Introduction

Tuberculosis (TB) is caused by the bacterium *Mycobacterium tuberculosis*, which is an airborne disease transmitted from person to person by aerosolized droplet nuclei (Varaine & Rich, 2014). The disease is spread in the air when people who are sick with pulmonary TB expel bacteria through coughing, sneezing, laughing or talking (Ministry of Public Health and Sanitation [MOPHS], 2009). Worldwide, Tuberculosis is among the top ten causes of death, third among the infectious diseases overtaking even HIV (World Health Organization [WHO], 2016). In 2012 8.6 million people developed the disease, 1.3 million died (WHO, 2013).

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Tuberculosis (TB) remains one of the most pressing public health concerns globally, particularly in developing countries. According to the World Health Organization (WHO, 2023), TB is among the top 10 causes of death worldwide and a leading cause of death from a single infectious agent, surpassing HIV/AIDS. Nigeria is among the 30 high TB-burden countries, contributing significantly to the global TB incidence rate. The Federal Ministry of Health (FMOH, 2021) reports that over 440,000 new TB cases are recorded annually, with an estimated 150,000 deaths each year due to TB and its complications.

Sokoto State, located in north-western Nigeria, is among the states with a significant TB burden. In 2021, the state diagnosed 18,366 TB cases, which doubled the 9,267 cases diagnosed in 2020 (Healthwise, 2022). As of November 2021, no fewer than 13,486 residents of Sokoto State were receiving TB treatment at different locations across the state (Sokoto introduces house-to-house search, 2022). Despite intensified efforts, TB control in Sokoto remains suboptimal due to: late diagnosis and under-reporting, especially among children and rural dwellers; limited access to diagnostic tools like GeneXpert and radiography; inadequate training for healthcare workers on MDR-TB and TB-HIV co-infection; poor treatment adherence due to poverty, stigma, and limited DOTS coverage; and weak integration of TB with HIV services and poor patient follow-up systems.

The social determinants of health in Sokoto State create a context of profound vulnerability that affects TB management. Recent community-based research has documented that the population faces severe socioeconomic deprivation. Musa et al. (2026c) identified three independent predictors of poor health outcomes: low household dietary diversity (AOR = 4.2, 95% CI: 1.8–9.8), low maternal education (AOR = 3.1, 95% CI: 1.3–7.4), and extreme household poverty (AOR = 2.8, 95% CI: 1.2–6.5). The study found that 73.3% of households consume four or fewer food groups daily, 45.3% live in extreme poverty earning less than N20,000 per month, and 75.3% of caregivers have secondary education or less (Musa et al., 2026b). Furthermore, 65.3% of households live more than 5 kilometers from a health facility, and only 45.3% of children are fully immunized (Musa et al., 2026a). These social determinants create significant barriers to TB care-seeking, diagnosis, and treatment adherence.

The Health Belief Model (HBM) explains health behavior based on perceived susceptibility, severity, benefits, and barriers. It is useful in understanding TB treatment adherence and health-seeking behavior (Rosenstock, 1974). The model posits that individuals are more likely to take health-related actions if they perceive themselves to be susceptible to a condition, perceive the condition as severe, believe that taking action would be beneficial, and perceive few barriers to taking action. In the context of TB, the HBM helps explain why some patients adhere to treatment while others default. Patients who perceive TB as a serious threat and believe that treatment will be effective are more likely to complete their treatment regimen. Conversely, patients who perceive significant barriers such as stigma, transportation costs, or side effects are more likely to default.

Andersen's Health Care Utilization Model (AHCUM) explains healthcare utilization through predisposing factors (such as education and health beliefs), enabling factors (such as income, insurance, and proximity to health facilities), and need factors (both perceived and clinically evaluated). It provides insight into access and utilization of TB services (Andersen, 1995). Andersen's model is particularly relevant for understanding why some populations have better access to TB services than others. Predisposing factors such as education and health beliefs influence individuals' propensity to seek care. Enabling factors such as income, insurance, and proximity to health facilities determine whether individuals can access care. Need factors, both perceived and clinically evaluated, trigger the actual use of services.

This study assessed the social determinants affecting TB management in Sokoto State from 2020 to 2024, including stigma, awareness, and geographic accessibility, within the context of the broader social determinants documented in the state.

2. Materials and methods

2.1. Study Area

This research work was carried out in Sokoto metropolis, Sokoto located within the latitude 13° 12' 98" N, longitude 5° 20' 36' E and altitude 302 m above the sea level. Sokoto is located in the North West of Nigeria, between latitudes 13° 4' 07" north and longitudes 05° 14' 49" east and above 265 m the sea level. The State accounts for 2.3% of Nigeria's total population. Situated in the North Western corner of Nigeria, Sokoto State territory occupies 25,973 square kilometres. Sokoto shares its borders with Niger Republic to the North, Zamfara State to the East, Kebbi state to the South-West (MOCIT, 2002). The State has an estimated population of about 6,391,000 people as of 2023 with 95.9 persons per square kilometre, and 3% growth rate annually (National Population Commission [NPC], 2023).

2.2. Study Design

This study adopted a descriptive cross-sectional design to collect quantitative and qualitative data from health workers, patients, and public health officials involved in TB care. The Health Belief Model and Andersen's Health Care Utilization Model served as the theoretical frameworks.

2.3. Study Population

The target population includes: Health workers in TB clinics, Patients currently undergoing TB treatment and Public health officers responsible for TB program supervision.

2.4. Inclusion and Exclusion Criteria

- **Inclusion Criteria:** Confirmed TB Diagnosis, Receiving TB Treatment in Sokoto State, Age Criteria, Availability of Medical Records, Consent to Participate and Involvement in TB Management (for Health Workers).
- **Exclusion Criteria:** Patients Not Resident in Sokoto State, Patients with Multi-Drug Resistant TB (MDR-TB), Incomplete Records, Pediatric TB Cases, Participants with Co-morbidities and Non-TB Health Workers.

2.5. Sample Size Determination

The sample size was computed using the Yamane (2007) formula: $n = N / [1 + N(e)^2]$, where N = total number of DOTS centres in Sokoto State (496), e = margin of error (0.05). Thus, n = 221 DOTS centres were selected for facility-level assessment. Additionally, all 20 TB diagnostic centres (GeneXpert/Truenat sites) were included purposively due to their specialized role.

For patient record review, the sample size was calculated using the single population proportion formula (Daniel, 1999): $n = Z^2 p (1-p) / d^2$, where Z = 1.96, p = estimated treatment success rate (97%), and d = 0.03. A minimum of 124 patient records was required; to account for missing data, 150 patient records were sampled. The final sample comprised 200 respondents.

2.6. Sampling Techniques

Simple random sampling method was employed during data collection. Simple random sampling technique was employed where a computer was used to generate a series of random numbers. A list of all the staff dealing with TB patients was entered in an excel sheet. A function =RAND () was used to generate random numbers between 0 and 1. Then, sorted both columns with the list of names and the random number by the random numbers. This rearranged the list in random order from the lowest to the highest random number.

2.7. Instrument for Data Collection

Data was collected retrospectively by trained health professionals using structured checklist. The primary data was collected using structured questionnaire organized into seven sections namely introduction, socio demographic profile, Turnaround time as a component of quality management systems and TB patient treatment, result accuracy as a component of quality management systems and TB patient treatment, drug inventory as a component of quality management systems and TB treatment, monitoring and evaluation as a component of quality management systems and TB treatment and data management as a component of quality management and TB treatment.

2.8. Data Collection

- **Quantitative Data Collection:** Trained research assistants visited each selected DOTS centre and diagnostic facility. From each facility, TB registers (2020–2024) were accessed after permission. At selected DOTS centres, consecutive TB patients presenting for follow-up or drug refill were invited to participate. After obtaining informed consent, trained interviewers (fluent in Hausa and English) administered the PEIQ in a private room.
- **Qualitative Data Collection:** The lead researcher conducted KIIs at participants' offices or a neutral location. Interviews were audio-recorded (with permission) and transcribed verbatim. FGDs were held in community settings (health centres, schools, or religious halls) after community entry and mobilisation. Each FGD was facilitated by a trained moderator and an assistant who took notes. Sessions lasted 60-90 minutes, were audio-recorded, and transcribed in Hausa then translated to English.

Data collection occurred over a 3-month period (June-August 2025).

2.9. Statistical Analysis

Data was analyzed using IBM SPSS version 25 for windows. Categorical variables were summarized using frequencies and percentages.

2.10. Ethical Considerations

This study adhered to the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Health Research Ethics Committee of the Sokoto State Ministry of Health (Ref: SKHREC/052/2025). Permission was also secured from the SSPHCDA and local government authorities.

3. Results

3.1. Socio-Demographic Characteristics

Table 1 Socio-Demographic Characteristics of Respondents (n = 200)

Variable	Category	Frequency	Percentage (%)
Sex	Male	118	59.0
	Female	82	41.0
Age	18–29 years	52	26.0
	30–39 years	60	30.0
	40–49 years	45	22.5
	50 years and above	43	21.5
Educational Level	No formal education	65	32.5
	Primary	58	29.0
	Secondary	47	23.5
	Tertiary	30	15.0
Occupation	Health Worker	80	40.0
	TB Patient	55	27.5
	Public Health Officer	65	32.5

Source: *Field Survey Data (2025)*

The majority of respondents were male (59.0%), with most within the economically active age group of 30–49 years (52.5%). A significant proportion (32.5%) had no formal education, while only 15.0% attained tertiary education.

3.2. Barriers to Effective TB Management

Table 2 Barriers to Effective TB Management (n = 200)

Barrier	Frequency (n)	Percentage (%)
Stigma and discrimination	72	36.0
Poor awareness/health education	60	30.0
Drug stock-outs	18	9.0
Long distance to treatment centers	25	12.5
Poor patient follow-up	15	7.5
Others	10	5.0

Source: *Field Survey Data (2025)*

Table 2 highlights the barriers to effective TB management, from the table stigma and discrimination (36.0%) as the most significant barrier to effective TB management, followed by poor awareness (30.0%). These findings emphasize the need for intensified community engagement and health education. Other barriers such as long travel distances (12.5%) and inadequate patient follow-up (7.5%) further affect treatment adherence, particularly in rural areas.

3.3. Treatment Outcomes

Table 3 Treatment Outcomes of TB Patients (2020–2024, n = 200)

Treatment Outcome	Frequency (n)	Percentage (%)
Cured	130	65.0
Completed Treatment	30	15.0
Defaulted	20	10.0
Died	10	5.0
Treatment Failure	5	2.5
Transferred Out	5	2.5

Source: Field Survey Data (2025)

The overall treatment success rate was 80.0% (65.0% cured, 15.0% completed treatment). The default rate was 10.0%, mortality 5.0%, treatment failure 2.5%, and transfer-out 2.5%.

3.4. Qualitative Findings

The narrative of Fatima Bello, a 32-year-old mother from Sokoto North LGA, illustrates how stigma and poor awareness manifest in Sokoto. She dismissed her persistent cough as ordinary malaria, and her husband believed it was a spiritual attack, leading to months of wasted time on herbs before reaching a hospital (Sokoto TB Programme, 2022). This case highlights the urgent need for community awareness and culturally sensitive interventions. This pattern of normalization of illness is consistent with the "perception gap" documented in concurrent research in Sokoto State, where only 22.7% of caregivers perceived malnutrition as a problem despite objective evidence showing 83.3% of children were underweight (Musa et al., 2026a).

The statement from the Lafia LGA TB and Leprosy Supervisor that "most people are still in denial and will not want to come out for testing or treatment until the cough or sickness is very severe" illustrates the stigma challenge (Breakthrough ACTION, 2024).

4. Discussion

4.1. Stigma and Discrimination

Stigma and discrimination (36.0%) emerged as the most significant barrier, consistent with extensive literature documenting the pervasive impact of TB-related stigma. Oshi et al. (2017) in Lagos found that stigma was associated with low notification rates, anxiety, depression, and poor health-related quality of life among people with DR-TB. In Northern Nigeria specifically, Magaji et al. (2025) reported that high stigma and limited community engagement significantly hinder TB detection and adherence. People with chronic, infectious diseases such as TB and HIV are generally stigmatized and avoided. Women suffer more stigma and discrimination than men, making them reluctant to seek care for TB until the disease is advanced.

The narrative of Fatima Bello, cited in the Sokoto TB Programme (2022) report, illustrates how stigma manifests in Sokoto, her husband believed her persistent cough was a spiritual attack rather than a medical condition, leading to months of delay before seeking appropriate care. Musa et al. (2024) similarly documented that in Northwestern Nigeria, TB is often attributed to supernatural causes or moral failings, leading to social ostracism and delayed care-seeking. This pattern of normalization of illness has been documented in concurrent research in Sokoto State. Musa et al. (2026a) found a "perception gap" where only 22.7% of caregivers perceived malnutrition as a problem despite objective evidence showing 83.3% of children were underweight and 68.7% suffered from acute malnutrition. This normalization of illness means that TB symptoms such as persistent cough may be dismissed as routine or attributed to non-medical causes, delaying care-seeking until the disease is advanced.

The statement from the Lafia LGA TB and Leprosy Supervisor that "most people are still in denial and will not want to come out for testing or treatment until the cough or sickness is very severe" illustrates the stigma challenge (Breakthrough ACTION, 2024). Many suspected cases of coughing are not reported in hospitals, resulting in self-medication by patients, which often results in deaths in homes and spikes community spread of the disease (Breakthrough ACTION, 2024).

Addressing stigma requires multi-level interventions: community awareness campaigns, engagement of religious and traditional leaders, peer support programs, and integration of TB services into general health services to normalize care-seeking. The success of peer educator programs, exemplified by Fatima Bello becoming a volunteer after her recovery (Sokoto TB Programme, 2022), suggests that involving recovered patients in awareness efforts can be particularly effective.

4.2. Poor Awareness and Health Education

Poor awareness (30.0%) was the second most frequently cited barrier, reflecting the low educational levels documented in this study (32.5% no formal education). This finding is consistent with broader educational deprivation in Sokoto State. Musa et al. (2026b) found that 75.3% of caregivers have secondary education or less, and only 10% have attained tertiary education. Low maternal education was identified as an independent predictor of poor health outcomes (AOR = 3.1, 95% CI: 1.3-7.4) (Musa et al., 2026c). Legesse et al. (2010) in Ethiopian pastoral communities found that poor knowledge about TB causation, transmission, and curability was associated with delayed care-seeking and preference for traditional healers. In Sokoto, similar dynamics appear to operate, with many patients initially attributing symptoms to malaria or spiritual causes (Shehu, 2023).

The finding that only 27.5% of respondents were TB patients (the majority were health workers and public health officers) may have underestimated the true extent of awareness gaps in the general population. Obuku et al. (2012) in Ugandan slums found that TB knowledge was generally poor, with significant proportions of respondents unaware that TB is curable or that it is transmitted through the air.

Accurate information and health literacy about TB in the community remain the bedrock of stigma reduction, improved health-seeking behavior, increased TB case-finding, and notification (Breakthrough ACTION, 2024). A study in Lagos State found that among urban slum dwellers, only 27.2% were aware of a TB treatment facility, 41.6% knew that TB treatment is free, 48.4% knew that TB is curable, and only 31.5% knew who a presumptive TB patient is (Breakthrough ACTION, 2024). This low level of awareness underscores the importance of community engagement strategies.

Targeted health education using culturally appropriate channels (radio, community meetings, religious gatherings) is urgently needed. Sokoto State has prioritized community sensitization. Up to 40% of community sensitization efforts have been directed to religious settings, especially prayer houses, leveraging the influence of religious leaders to promote TB awareness and care-seeking (Sokoto's Tuberculosis fight, 2026). The state has also established sample transport mechanisms requiring frequent renegotiations with commercial boat riders to reach hard-to-reach communities (Sokoto's Tuberculosis fight, 2026). Children are transported to access free but distant chest X-ray services provided by The Global Fund (Healthwise, 2022).

4.3. Geographic Accessibility

Long distance to treatment centers (12.5%) was identified as a barrier, reflecting the challenging geography of Sokoto State, where many LGAs are rural and remote with poor road infrastructure. The Sokoto TB Programme (2024) acknowledged the need for more vehicles and motorcycles to effectively cover hard-to-reach areas. This finding is consistent with the work of Bello et al. (2024), who found that travel distance was a significant predictor of treatment default in rural Northern Nigeria. Concurrent research in Sokoto State has documented that 65.3% of households live more than 5 kilometers from a health facility, with 22.7% facing journeys exceeding 10 kilometers (Musa et al., 2026a). This geographic marginalization creates a structural barrier to both preventive and curative care, undermining treatment adherence and follow-up.

The decentralization of TB services to primary health centers and community settings has been recommended as a strategy to address geographic barriers. Oladimeji et al. (2018) demonstrated that community-based MDR-TB treatment achieved comparable outcomes to hospital-based management (68% vs 65.5% success), with higher patient satisfaction and lower transportation costs. Sokoto State has made some progress in this direction through its house-to-house search strategy (Sokoto State Ministry of Health, 2022), but further decentralization is needed.

The finding that 54.7% of caregivers report commodity stock-outs and 84.7% perceive external support as inadequate (Musa et al., 2026a) further compounds the geographic accessibility challenge. When caregivers travel long distances to health facilities only to find that essential supplies are unavailable, it erodes trust in the health system and discourages future care-seeking. This is particularly concerning for TB patients who require consistent treatment over 6–8 months.

4.4. Integration with Theoretical Frameworks

The findings of this study can be understood through the lens of the Health Belief Model (Rosenstock, 1974) and Andersen's Health Care Utilization Model (Andersen, 1995). According to the HBM, patients who perceived significant barriers such as stigma (36%) and poor awareness (30%) were more likely to default on treatment. The low perceived susceptibility (due to poor awareness) and high perceived barriers (stigma, distance, cost) contribute to delayed care-seeking and treatment default. The "perception gap" documented in Sokoto State where only 22.7% of caregivers recognized malnutrition as a problem despite 83.3% objective prevalence (Musa et al., 2026a), illustrates how low perceived susceptibility operates in this population.

Andersen's model explains how enabling factors (transportation, income, social support) and need factors (symptom severity) interact with predisposing characteristics (education, gender) to influence service utilization. The significant proportion of respondents with no formal education (32.5%) represents a predisposing factor that limits health literacy and care-seeking behavior. This is consistent with the finding that low maternal education is an independent predictor of poor health outcomes (AOR = 3.1) (Musa et al., 2026c). The long distance to treatment centers (12.5%) represents an enabling factor that limits access to care, consistent with the finding that 65.3% of households live more than 5 kilometers from a health facility (Musa et al., 2026a). Extreme poverty (45.3% earning <N20,000/month) (Musa et al., 2026b) represents another enabling factor that constrains access to care, as transportation costs and lost wages can make treatment unaffordable even when services are free.

The synergistic interaction of these social determinants creates a syndemic of vulnerability. Musa et al. (2026c) identified three independent predictors of poor health outcomes: low dietary diversity (AOR = 4.2), low maternal education (AOR = 3.1), and extreme poverty (AOR = 2.8). These factors interact to create a population highly vulnerable to TB and its complications. The high prevalence of malnutrition (83.3% underweight), micronutrient deficiencies (91.3% vitamin A deficiency, 73.3% zinc deficiency), and systemic inflammation (78.0% elevated CRP) documented in Sokoto State (Musa et al., 2026d, 2026e) represent biological pathways through which social determinants are embodied, compromising immune function and increasing susceptibility to TB infection and poor treatment outcomes.

5. Conclusion

Social determinants, particularly stigma and discrimination (36%) and poor awareness/health education (30%), significantly impede TB control in Sokoto State. Geographic accessibility (12.5%) and poor patient follow-up (7.5%) further compound the problem. These findings must be understood within the broader context of profound socioeconomic deprivation in Sokoto State, where 83.3% of children are underweight, 91.3% are vitamin A deficient, 73.3% of households consume ≤ 4 food groups daily, 45.3% live in extreme poverty, and 75.3% of caregivers have secondary education or less (Musa et al., 2026a, 2026b, 2026c). The "perception gap" where only 22.7% of caregivers recognized malnutrition as a problem despite 83.3% objective prevalence (Musa et al., 2026a) illustrates the normalization of illness that underlies poor health-seeking behavior. The Health Belief Model and Andersen's Health Care Utilization Model effectively explain the pathways through which these social determinants influence health-seeking behavior and treatment adherence.

Recommendations

- **Implement community-based stigma reduction interventions:** Engage religious and traditional leaders, establish peer support programs, and involve recovered patients in awareness efforts. The success of peer educator programs, exemplified by Fatima Bello, suggests that involving recovered patients can be particularly effective. Address the cultural beliefs and misconceptions documented in Sokoto State, where illness is often attributed to supernatural causes (Musa et al., 2024).
- **Develop culturally appropriate health education materials:** Use Hausa and local languages, employing multiple channels including radio (the most accessible medium in rural areas), religious gatherings (mosques and churches), community meetings, and school health programs. Address the low educational levels (32.5% no formal education) documented in this study and the broader educational deprivation where 75.3% of caregivers have secondary education or less (Musa et al., 2026b).

- **Decentralize TB services:** Move TB care beyond general hospitals into primary health centres and community settings to improve access for rural populations. The house-to-house search strategy should be scaled up. Address the geographic accessibility barrier documented in 65.3% of households living >5 km from a health facility (Musa et al., 2026a).
- **Address socioeconomic barriers:** Provide nutritional support and transportation subsidies to reduce catastrophic costs for TB-affected households. The NTBLCP reports that 71% of TB-affected households face catastrophic expenses, with over 20% of household income spent on transportation, nutrition, and other indirect costs despite free treatment being available. Address the extreme poverty (45.3% earning <N20,000/month) and low dietary diversity (73.3% consuming ≤4 food groups) documented in Sokoto State (Musa et al., 2026b, 2026c).
- **Strengthen community engagement:** Scale up house-to-house search strategies and peer educator programmes like the one described by Fatima Bello, who became a volunteer peer educator after her recovery. Address the "perception gap" by helping communities recognize illness as preventable and treatable rather than an inevitable fact of life (Musa et al., 2026a).
- **Address the malnutrition-inflammation syndemic:** Integrate nutritional assessment and support into TB programs. Given that 91.3% of children in Sokoto State are vitamin A deficient, 73.3% are zinc deficient, 78.7% are anemic, and 78.0% have elevated CRP (Musa et al., 2026d, 2026e), TB patients should be screened for nutritional deficiencies and provided with appropriate supplementation. Address the underlying environmental drivers of inflammation, including 35.3% open defecation and recurrent infections (Musa et al., 2026b).
- **Conduct further operational research:** Evaluate the effectiveness of different stigma reduction interventions (e.g., community dialogue, peer support, mass media campaigns) in the Sokoto context, and assess the impact of integrated social-nutrition-health interventions on TB outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

This study adhered to the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Health Research Ethics Committee of the Sokoto State Ministry of Health (Ref: SKHREC/052/2025). Permission was also secured from the SSPHCDA and local government authorities. The present research work does not contain any studies performed on animals/humans subjects by any of the authors'.

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