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Climate Change and Dengue Vulnerability in Marginalized Communities in Bangladesh: A Public Health Review

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ABSTRACT:

Dengue fever, a mosquito-borne viral disease, has emerged as a significant public health challenge in Bangladesh. Climate change, manifested through rising temperatures, erratic rainfall, and extended monsoon seasons, has intensified dengue transmission. Marginalized communities, particularly urban slum dwellers, flood-prone rural populations and Rohingya refugees are disproportionately vulnerable due to poor housing, inadequate sanitation and limited access to healthcare. This review explores the relationship between climate change and dengue outbreaks in Bangladesh, focusing on marginalized populations. It assesses existing vector control measures, identifies gaps in current public health strategies and highlights best practices from other dengue-endemic countries. Findings suggest that integrating climate surveillance, community-based mosquito control, and targeted interventions in high-risk areas can strengthen Bangladesh's response to dengue. This review provides a policy-oriented perspective to enhance climate-adaptive health strategies.

KEYWORDS:

Dengue, viral Disease, Public Health, Community

1. Introduction

Dengue fever, transmitted primarily by Aedes aegypti mosquitoes, has become one of Bangladesh's foremost public health concerns. The 2023 outbreak, which resulted in approximately 321,179 hospitalizations and 1,705 deaths, stands as the deadliest on record a crisis driven by climatic factors like unprecedented rainfall, elevated temperatures and high humidity that expanded the mosquito breeding season across the nation (1).Variables such as temperature, rainfall, and humidity are known to influence dengue transmission by accelerating mosquito development, enhancing vector survival, and reducing viral incubation periods (2,3). Projections indicate that under continued warming, Bangladesh may experience longer dengue seasons and intensified transmission cycles (4).

Multiple global and local studies substantiate the link between climate change, urbanization, and expanding dengue risk. Globally, the population living in areas with high climate suitability for dengue (based on temperature and humidity) has grown by an estimated 2.5 billion between 1979 and 2022 (5). In Bangladesh, rapid urban expansion, dense population growth and suboptimal urban infrastructure have intensified vector habitats and disease transmission (6,7).

Dengue outbreaks are now extending beyond traditional monsoon months into earlier and later parts of the year, exacerbating strain on health systems and increasing population vulnerability. The interplay between climate and urban dynamics is fueling both more frequent and more widespread dengue epidemics.

Marginalized populations urban slum dwellers, ethnic minorities, rural "char" islands and low-income residents face heightened exposure to dengue due to a convergence of environmental and social inequities. Urban slums often lack proper drainage, sanitation, and water supply, enabling persistent mosquito breeding in stagnant water and open containers (8). In coastal and riverine areas, rising salinity, waterlogging and recurrent flooding undermine livelihoods, food security, housing stability and access to health services (4).

Recent research focusing on marginalized communities in southern Bangladesh highlights

how socio-economic disadvantage, limited adaptive options, and geographic isolation exacerbate vulnerability to climate impacts, including vector-borne diseases like dengue. Additionally, youth-based studies reveal gaps in climate–dengue awareness; although knowledge is important, it does not always translate into protective action without context-specific interventions (9).

Climate justice frameworks call attention to the disproportionate influence of climate change on those with the least ability to adapt an inequity magnified in health outcomes such as dengue incidence and severity (10).

While numerous studies have examined broad dengue–climate dynamics, only a handful integrate detailed socio-demographic analysis focusing on marginalized communities. Most studies concentrate on climatic parameters or general population trends, leaving a critical gap in understanding how intersecting vulnerabilities shape disease risks (5).

Moreover, while knowledge and perception regarding climate–dengue relationships are gaining academic attention, research examining behavior change and protective actions remains scant (9). Studies assessing policy frameworks and public health readiness often overlook the needs of marginalized groups whose access to services and information is limited (11).

Lastly, there exists a shortage of targeted research that combines climate projections, urban planning deficiencies, health system preparedness, and social vulnerability into one cohesive perspective, an integrated approach essential for crafting effective, equitable interventions.

By integrating climatology, urban studies, public health, and social vulnerability frameworks, the review seeks to inform more just, effective strategies that prioritize the needs of Bangladesh's most at-risk communities.

2. Methodology

For this review, we focused on the relationship between climate change and dengue transmission, with particular emphasis on the impacts of rising temperatures, changing rainfall patterns, urbanization, public health preparedness and social vulnerability. Relevant literature published between 2012 and 2025 was systematically searched in several electronic databases, including Google Scholar, PubMed, ScienceDirect and Web of Science. The search strategy employed combinations of keywords such as "dengue," "climate change," "global warming," "temperature," "rainfall," "urbanization," "vector-borne diseases," "Aedes mosquitoes," "public health preparedness," and "social vulnerability." After screening the retrieved records, duplicate publications, editorials, commentaries, letters to the editor, conference abstracts and studies not directly related to dengue and climate-related determinants were excluded. Priority was given to original research articles, epidemiological studies, modeling studies and relevant reports that provided evidence on the influence of climatic and socio-environmental factors on dengue transmission. The selected studies were critically evaluated and synthesized to identify key trends, research gaps and future directions in understanding and mitigating climate-sensitive dengue risk (Figure 1).

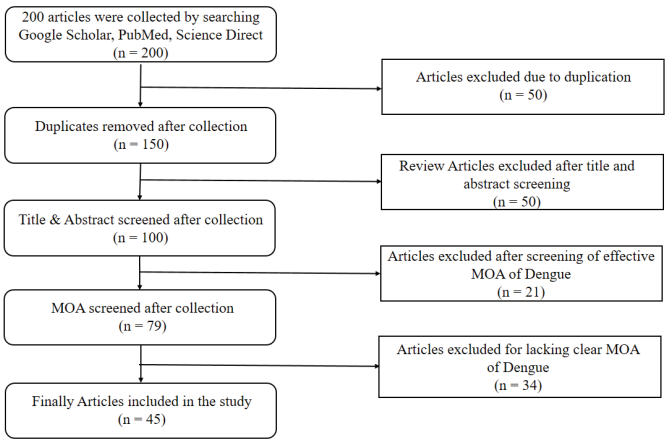


Figure 1: A schematic illustration outlining the methodology to search for and select relevant literature.

3. Climate Change and Dengue: A Growing Public Health Concern

3.1. Rising Temperatures and Increased Mosquito Survival Rates

Climate change has led to rising temperatures in Bangladesh, creating favorable conditions for the Aedes mosquitoes that transmit dengue fever. Warmer temperatures accelerate the mosquito life cycle, leading to higher reproduction rates and increased vector populations. Additionally, elevated temperatures shorten the extrinsic incubation period of the dengue virus within

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mosquitoes, enhancing the likelihood of transmission to humans. This combination of factors contributes to a higher incidence of dengue cases.

A study highlights that elevated temperatures expedite the mosquito life cycle, resulting in heightened breeding rates and shorter virus incubation periods within mosquitoes. These changes increase the probability of successful viral transmission to humans(9).

According to a report by Reuters (2024), rising temperatures and prolonged monsoon seasons in Bangladesh due to climate change have created ideal conditions for the Aedes aegypti mosquito, leading to a surge in infections.

3.2. Unpredictable Rainfall and Expansion of Mosquito Breeding Grounds

Climate change has altered precipitation patterns in Bangladesh, leading to periods of intense rainfall followed by dry spells. These fluctuations create stagnant water pools in urban areas, providing ideal breeding sites for Aedes mosquitoes. The accumulation of water in containers, discarded tires and other debris becomes a breeding ground, increasing mosquito populations and the risk of dengue outbreaks.

Research indicates that rainfall, maximum temperature and relative humidity significantly influence vector abundance and subsequent dengue cases in Dhaka city, Bangladesh. The study found that these climatic factors could explain 61% of the variability in reported dengue cases with a two-month lag period (2).

A study projected that a moderate increase in rainfall would create more breeding sites for immature vectors, resulting in a larger dengue fever epidemic (12).

3.3. Longer Monsoon Seasons and Year-Round Transmission Risks

Traditionally, Bangladesh's monsoon season occurred from June to August. However, climate change has extended the monsoon period from July to early October, leading to prolonged periods of rainfall. This extended monsoon season results in prolonged mosquito breeding opportunities and a longer window for dengue virus transmission.

According to a report, rising temperatures and a longer monsoon season in Bangladesh due to climate change are providing ideal breeding conditions for the dengue-spreading mosquito.

A study projected that a moderate increase in rainfall would create more breeding sites for immature vectors, resulting in a larger dengue fever epidemic (13).

4. Marginalized Communities: The Worst Affected by Dengue in Bangladesh

4.1. Urban Slums and Dengue Exposure

Rapid urbanization in Bangladesh has led to the proliferation of informal settlements lacking adequate infrastructure. In Dhaka, unplanned urban growth has resulted in poor housing conditions, inadequate sanitation, and stagnant water accumulation, creating ideal breeding grounds for mosquitoes. Residents in these areas often live near open sewers and have limited access to clean water, increasing their exposure to dengue (8).

The correlation between stagnant water and dengue incidence is well-documented. A study highlighted that the presence of water containers around homes significantly increases the risk of dengue infection. Moreover, the lack of community awareness and limited healthcare access exacerbate the situation, leading to delayed diagnosis and treatment (14).

4.2. Flood-Prone Rural Areas and Dengue Risk

Bangladesh's geographical location makes it susceptible to frequent flooding, especially in rural regions. Floodwaters often stagnate, providing breeding sites for mosquitoes. Research indicates that stagnant floodwaters have heightened the threat of dengue fever in these areas (15).

The 2024 floods in Sylhet District submerged vast areas, affecting over 825,000 people and creating conditions conducive to mosquito proliferation. The disruption of healthcare services during such disasters further hampers effective disease management and control.

4.3. Rohingya Refugee Camps and Dengue Epidemics

The Rohingya refugee camps in Cox's Bazar

are among the most densely populated areas in Bangladesh. Overcrowding, inadequate sanitation and poor waste management have turned these camps into hotspots for dengue transmission (16).

Waste accumulation and waterlogging due to poor drainage systems have been identified as primary contributors to mosquito breeding in the camps (17). Additionally, the monsoon season exacerbates these challenges, leading to increased disease outbreaks (18).

5. National Dengue Prevention and Control Strategy (2024–2030)

The Ministry of Health has drafted the first-ever National Dengue Prevention and Control Strategy (2024–2030)(19). It emphasizes six pillars:

1. Enhancing capacity of doctors, nurses and hospitals
2. Strengthening disease and vector surveillance
3. Ensuring multisectoral participation
4. Promoting effective community engagement
5. Early case detection
6. Prompt, effective case management

6. Current Government-led Strategies in Bangladesh

However, experts caution about the strategy's potential overemphasis on clinical care vs. preventive control, particularly vector control (16).

6.1. Outbreak Response Measures (2023–2024)

During the devastating 2023 outbreak Bangladesh's deadliest, with over 321,000 hospital admissions and 1,705 deaths emergency actions included (20): Increasing hospital capacity and repurposing facilities, coordinated mosquito breeding site elimination and spraying, awareness campaigns leveraging religious institutions and international aid from WHO and UNICEF for surveillance, logistics, staff training and testing kits (20). Despite these efforts, challenges persisted like medical supply shortages and systemic strain (21,22).

6.2. Inadequate Climate Adaptation Integration

A scoping review of Bangladesh's health system found limited integration of climate change considerations. Of 29 operational plans under the Health Sector Program, only 15 mentioned or fully integrated climate concerns; the remaining 14 lacked any climate component. Additionally climate-specific indicators and budgeting mechanisms are missing, public-private sector coordination on climate readiness is negligible; also a draft Health National Adaptation Plan (HNAP) exists but remains outside operational frameworks and lacks clear implementation pathways (11).

6.3. Weak Surveillance and Early Warning Systems

There is no operational climate-based dengue early warning system, despite strong evidence of climate sensitivity. Research shows even a single extra rainy day can increase dengue cases by ~6% in the following month. However, these findings have yet to translate into policy or surveillance mechanisms (23,24).

6.4. Insecticide Resistance and Vector Control Challenges

Mosquito control relies on chemical insecticides (pyrethroids, carbamates, etc.), but studies confirm high levels of resistance, particularly to permethrin among Aedes aegypti. Control efforts are also hampered by limited access to premises, especially in dense urban areas like Dhaka. Structural issues budget, management, evaluation further hinder efficacy (25).

6.5. Gaps in Community Engagement

Although community engagement is recognized in policy, the actual practice is fragmented. A 2024 cross-sectional study in Dhaka found that while 92% of respondents see community effort as vital, knowledge and participation were poor, with disparities across demographic groups. Coordinated, multisectoral engagement involving NGOs, religious leaders and community stakeholders remains limited (26).

6.6. Knowledge–Practice Disconnect

Nationwide KAP (Knowledge, Attitude, Practice) studies show that while awareness about dengue is moderate-to-high, preventive practices are low. For example: Only 13% cited environmental cleaning as a preventive measure (27).

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7. Analysis and Recommendations

7.1. Strengthen Climate-Responsive Surveillance and Early Warning

Integrate meteorological data into real-time surveillance to predict dengue surges. Automated climate health dashboards could rely on comprehensive data (rainfall, temperature, humidity), enabling proactive control mirroring efforts in other contexts (24).

7.2. Operationalize the Health National Adaptation Plan (HNAP)

Adopt the HNAP into the Health Sector Program with:

- Climate-specific indicators and dedicated funding
- Enhanced public–private coordination
- Measurable outreach targets for vulnerable regions (11)

7.3 Diversify Vector Control Strategies

To counter resistance and logistic challenges one needs to explore Wolbachia-based biocontrol, shown as environment-friendly and scalable (28) and rotate insecticides and deploy alternatives (malathion, registered elsewhere) (24).

7.4. Deepen Community Engagement

Design tailored, inclusive engagement strategies are launching ongoing environmental cleaning drives, especially around religious hubs (mosques, temples), training local influencers and health volunteers in behavior change communications and institutionalize multi-sector collaboration (health, NGOs, religious councils, LGIs) (26,29).

8. Global Best Practices: Lessons for Bangladesh

8.1. Sri Lanka's Community-Based Mosquito Control

8.1.1. Household-Level Waste Management in Gampaha District

An intervention study carried out in Gampaha, an area with high dengue endemicity demonstrated that community mobilization for household-level waste management effectively reduced mosquito breeding. The program involved building local partnerships, promoting composting of biodegradable waste, raising awareness about solid waste and dengue, and improving garbage collection in collaboration with local authorities. Despite no significant differences in larval indices between treatment and control clusters, the intervention achieved a significant reduction in pupal indices, indicating a lower density of adult vectors (30).

Takeaway for Bangladesh: Mobilizing communities to manage household waste and eliminate breeding sites can be effective, especially when paired with structured local authority collaboration.

8.1.2. Digital Crowdsourcing for Community Engagement

A more recent initiative leveraged digital crowdsourcing methods during COVID-19 to engage communities in Sri Lanka's dengue control efforts. Through open calls, individuals submitted innovative ideas for instance, distributing Wolbachia-infected mosquito release boxes, integrating digital monitoring tools and proposing social and economic incentives to drive community action. The digital campaign achieved widespread reach, garnering 346,810 impressions over two weeks and demonstrating the potential of digital platforms to boost engagement (31).

Takeaway for Bangladesh: Digital platforms such as open-call competitions or mobile reporting apps can amplify community-driven strategies, especially important in urban or tech-connected regions.

8.1.3. Social Mobilization and Behavioral Change

A study assessing social mobilization campaigns in a high-risk area of Colombo found that knowledge and awareness alone did not translate into behavioral change. While knowledge levels were low, contributions to control activities were generally positive but actual practices lagged. The study highlighted the need for better understanding community perceptions and the sociocultural context to improve behavior uptake (31).

Takeaway for Bangladesh: Community outreach must go beyond awareness; messaging should be culturally tailored, leveraging local perceptions and behavioral drivers to effectively influence preventive actions.

8.2. Singapore's Early Warning System

8.2.1. Three-Month Real-Time Dengue Forecast Models (LASSO-Based)

Singapore's Environmental Health Institute (EHI) uses a real-time, three-month dengue forecasting system built using LASSO (Least Absolute Shrinkage and Selection Operator) regression. It integrates weekly epidemiological case data, meteorological data, vector surveillance indices and demographic statistics. This system accurately forecast the 2013 dengue peak, predicting 863 cases (actual peak: 842), which enabled earlier government response and more targeted resource deployment (32)

Takeaway for Bangladesh: Establishing a climate-informed, data-driven early warning system can preempt dengue surges and facilitate proactive intervention.

8.2.2. Other Modeling Approaches and Climate Integration

Further research highlights Singapore's use of machine learning models such as XG Boost, SVM and random forests to predict dengue incidence using meteorological variables such as solar radiation, UV index, cloud cover, precipitation and dew point. The XG Boost model, incorporating lagged climatic data up to 12 weeks, achieved an impressive R^2 of 0.83 in explaining variance in cases (33).

Takeaway for Bangladesh: Incorporating sophisticated ML models with lagged climate variables can bolster prediction accuracy and timing, enabling finer-scale forecasting.

8.2.3. Community and Policy Integration During Outbreaks

During the 2013 outbreak (22,000+ cases), Singapore activated an inter-agency alert system based on epidemiological modeling and color-coded community alerts. Local volunteers were mobilized as 'dengue fighters,' penalties were enforced for breeding-site negligence and budgets and inspections increased significantly (34).

Takeaway for Bangladesh: Early warnings must translate into coordinated action through multi-sector collaboration, public alerts, community mobilization and enforcement.

8.3. Brazil's Disease Surveillance Model

8.3.1. Climate-Integrated Surveillance

Brazil's Info Dengue system in Rio de Janeiro integrates epidemiological case notifications, weather data (temperature, humidity) and satellite imagery to produce weekly risk indicators. It facilitates timely surveillance of dengue and related arboviruses. The system's use of near-real-time data supports informed public health responses (35)

Takeaway for Bangladesh: A similar integrated system, combining health and climate data with satellite inputs, could enable near-real-time tracking and improve control precision.

8.3.2. AI-Driven LSTM Forecasting with Mobility and Climate

A preprint study tested a Long Short-Term Memory (LSTM) model in Brazil that forecasts weekly dengue cases by integrating historical cases, lagged climate variables and human mobility-adjusted imported cases. This mobility enhanced LSTM outperformed other models across accuracy metrics (MAE, MAPE, CRPS) and classification performance (sensitivity, F1 score) (36).

Takeaway for Bangladesh: Dynamic models that incorporate mobility, not just climate and case data, can better capture dengue transmission dynamics in urbanized regions.

8.3.3. Wolbachia-Based Mosquito Release and Integrated Response

Brazil is also advancing with Wolbachia-based biological control in partnership with the World Mosquito Program and Fiocruz. In Niterói, this approach led to a ~60% reduction in dengue and chikungunya cases. Additionally, Brazil established a national arbovirus control room to coordinate multilevel responses during outbreaks and climate-related surges (37).

Takeaway for Bangladesh: Investing in ecological biocontrol methods like Wolbachia, alongside institutional coordination hubs, can strengthen resilience toward severe outbreaks.

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Table 1: Cross-Cutting Insights for Bangladesh

Practice	What Made It Effective	Adaptation Opportunity for Bangladesh
Sri Lanka Community Interventions	Household waste cleanup + mobilized local governance	Launch local waste campaigns in high-risk zones; integrate with LGIs
Digital Crowdsourcing	Taps community creativity and outreach reach	Pilot mobile apps or crowdsourced contests for vector reduction ideas
Singapore Early Warning Systems	Integrates case, climate and vector data with LASSO/ML models	Build a national forecast dashboard to guide intervention timing
Community Alerts and Enforcement	Colour alerts, volunteers, interagency setup	Deploy traffic-light alerts and volunteer corps in urban wards
Brazil's InfoDengue and LSTM Models	Climate and mobility data for precision forecasting	Pilot an InfoDengue-like system using satellite and urban mobility data
Biocontrol and Coordination Room	Wolbachia releases and coordination enhance scope	Explore pilot Wolbachia projects and centralized outbreak response center

9. Policy Recommendations and Future Directions

9.1. Integrating Climate Surveillance into Bangladesh's Dengue Prevention Program

Bangladesh's dengue burden is increasingly influenced by climate variables. Rising temperatures, changing humidity patterns and irregular rainfall significantly affect mosquito dynamics and transmission cycles. A count regression study in Dhaka City confirms positive associations between temperature (both maximum and minimum), humidity and dengue incidence, while rainfall and sunshine exhibit complex effects (38). This suggests that climate data should be integral to dengue surveillance frameworks.

Moreover, the World Health Organization has supported a national workshop to integrate a One Health approach into the National Strategic Plan (NSP) for Dengue Surveillance, Prevention and Control. This includes multisectoral participation from health, environment, municipal and academic actors, emphasizing epidemiological and entomological data integration alongside behavioral and community insights (38).

9.2. Early Warning Systems and Climate-Based Dengue Tracking

Bangladesh lacks a formal climate-driven dengue early warning system. Embedding predictive capability into public health infrastructure could shift policy from reactive to proactive.

9.3. Modeling Potential

The aforementioned Dhaka study suggests building predictive models incorporating demography, entomology, immunology and climate variables all essential to forecast outbreaks (38).

9.4. Global Framework Inspiration

The Rockefeller Foundation underscores the need for integrated climate-health data systems, enhanced coordination, and improved communication. Their Urban Pulse framework cites Rio de Janeiro's predictive dengue model and Dhaka's heatwave protocol as exemplars (39).

9.5. Community-Based Interventions in Slums and Refugee Camps

Marginalized populations including slum dwellers and refugees bear disproportionate dengue burdens. Community-led solutions are crucial for sustainable control. Although there is limited research on refugee camps, parallels with slum settings suggest strong potential for community engagement. One study in Dhaka slums highlights gaps in knowledge–practice though residents understand dengue, preventive behaviors are inconsistent (40). The WHO's "One Health" initiative explicitly incorporates community awareness, behavioral insights and cultural considerations into control strategies. The integrated Aedes management (IAM) framework endorsed by WHO combines

environmental management, biological control, chemical measures and community engagement. Examples from Sri Lanka and India show success in reducing breeding via cleanup drives, Wolbachia releases, guppy fish use and school-based campaigns (41).

9.6. Cross-Cutting Coordination and Sustainability

The success of these interventions requires enabling structures:

9.6.1. Policy Coordination

Use the NGHS supported by the WHO's One Health workshop to align national, district, and local levels for integrated climate, surveillance, and response planning.

9.6.2. Data Infrastructure

Strengthen DGHS dashboards with climate and vector data, enabling visualization and decision support (39).

9.6.3. Resource Mobilization

Prioritize funding within the NSP for climate-health integration, model deployment, and community mobilization, potentially leveraging climate adaptation funds under UN frameworks (42).

9.6.4. Capacity Development

Train local government staff in climate surveillance, model interpretation and community engagement techniques.

10. Conclusion

Climate change has fundamentally reshaped the dengue landscape in Bangladesh transforming it from a monsoon-season issue into a pervasive, year-round public health threat. Recent data underscore how escalating temperatures, shifting rainfall patterns, and heightened humidity have extended favorable conditions for Aedes mosquitoes beyond the traditional June–September window. Reports from Dhaka and other regions highlight that October, November and even winter months now witness substantial dengue transmission, reflecting dramatic shifts in vector behavior and seasonality.

In this evolving climate context, marginalized communities, particularly in urban slums and overcrowded refugee settlements, bear an outsized burden. These populations lack adequate housing, sanitation and healthcare access, which intersects with altered environmental conditions to heighten exposure and limit resilience. For instance, women in slum areas face disproportionate risks due to constrained healthcare options and increased exposure in caregiving roles.

Given this intersection of systemic inequities and climate-aggravated health risks, a community-driven, adaptive dengue prevention approach is essential. Interventions must recognize that traditional short-term, monsoon-focused strategies are no longer sufficient. Putting power back into communities through targeted, locally led vector-control initiatives, including environmental cleanups, behavioral change campaigns, and locally adapted outreach, is critical. These must be designed with cultural competence to reach women, low-income families and other especially vulnerable groups. In summary, dengue in Bangladesh has transitioned into a non-seasonal, climate-driven health emergency, and the most vulnerable communities face the greatest risk. Effective response demands a climate-adaptive, community-embedded framework one that empowers disadvantaged populations, integrates localized insights and aligns health systems with the changing epidemiological landscape.

Author contributions

JMM and SJ conceptualized and designed the study methodology. JMM and SF edited the manuscript. All the authors read and approved the final version of the manuscript.

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Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

The consent for publication was obtained simultaneously with informed consent that was performed before sample collection.

Competing interests

The authors declare that they have no competing interests.

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