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Multilevel Determinants of Infection-Prevention Readiness in Health Facilities in Ghana: Facility, Environmental and Organisational Factors

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Research Article

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Abstract

Introduction:

Health-facility-associated infections (HFAIs), also referred to as healthcare-associated infections (HAIs), remain a major threat to patient safety globally, particularly in low- and middle-income countries where infrastructural deficiencies and weak infection prevention systems compromise healthcare delivery. In Ghana, limited empirical evidence exists on how facility-level, environmental, and organisational factors jointly influence infection-prevention readiness. This study aimed to examine the multilevel determinants of infection-prevention readiness in health facilities in Ghana.

Patients and Methods:

A cross-sectional analytical study was conducted using secondary data from 300 health facilities captured in the national Emergency Obstetric and Newborn Care (EmONC) assessment dataset across multiple districts in Ghana. Descriptive statistics were performed using SPSS version 26, while multilevel linear regression modelling was conducted in R to account for clustering of facilities within districts. Infection-prevention readiness was measured using a composite index constructed from validated indicators including water availability, sanitation facilities, electricity supply, and newborn service readiness.

Results

The null model revealed significant district-level clustering of infection-prevention readiness (ICC = 14.2%), justifying multilevel modelling. Environmental determinants were the strongest predictors of readiness. Functional toilets for staff ($\beta = 0.2209$, $p < 0.001$), running water in delivery rooms ($\beta = 0.3918$, $p < 0.001$), and availability of 24-hour newborn services ($\beta = 0.1975$, $p < 0.001$) were significantly associated with higher readiness scores. Organisational factors such as internet access showed weaker or non-significant associations after adjustment. The full model substantially reduced between-district variance.

Conclusion

Environmental and WASH-related factors are the strongest determinants of infection-prevention readiness in Ghanaian health facilities. Policy interventions should prioritise infrastructural investments in water supply, sanitation systems, and continuity of essential services to strengthen infection prevention and improve patient safety outcomes.

1. Introduction

Healthcare-associated infections (HAIs), also known as health-facility-associated infections (HFAIs), are infections acquired during the process of receiving healthcare and were neither present nor incubating at the time of admission. These infections usually occur at least 48 hours after admission or within 30 days following healthcare exposure (Haque et al., 2018). HAIs remain one of the most important threats to patient safety globally and are associated with prolonged hospital stays, increased morbidity, mortality, antimicrobial resistance, and substantial financial burdens on both households and health systems (World Health Organization, 2011; Witt et al., 2022).

Globally, approximately 5% to 10% of hospitalized patients acquire healthcare-associated infections, with nearly 1.7 million infections and more than 98,000 deaths reported annually (Burke, 2003; Haque et al., 2018). The burden is significantly higher in low- and middle-income countries (LMICs), where poor water, sanitation and hygiene (WASH) services, inadequate infection prevention and control (IPC) systems, infrastructural deficiencies, and limited surveillance systems increase vulnerability (Allegranzi et al., 2011; World Health Organization & UNICEF, 2021).

In Ghana, the economic and public health burden of HFAIs is substantial. Recent estimates suggest over 303,000 HFAI cases annually, resulting in approximately 31,360 additional deaths and an economic burden of US$1.57 billion, representing nearly 1.98% of Ghana's GDP and 4.6% of total health expenditure (WaterAid/World Bank, 2024). These figures highlight that HFAIs are not merely clinical complications but major health-system and economic concerns. Previous evidence from Ghana has also documented a substantial burden of healthcare-associated infections (Labi et al., 2019).

Previous studies in Ghana have reported important gaps in infection prevention readiness. Oppong et al. (2020) found uneven distribution of IPC programmes, poor governance structures, inadequate staffing, and weak resource availability across acute healthcare facilities. Similarly, Sunkwa-Mills et al. (2023) showed that behavioural compliance with IPC guidelines in maternity units was strongly influenced by infrastructural constraints, leadership gaps, and inconsistent supply systems.

The determinants of infection prevention operate across multiple interconnected levels. Facility characteristics such as ownership status, staffing levels, and electricity supply influence infection risk. Environmental factors including running water, sanitation facilities, waste management, and environmental cleanliness directly shape safe care delivery. Organisational factors such as leadership commitment, internet access, service continuity, and newborn service readiness also affect infection-prevention performance (World Health Organization, 2016; Storr et al., 2017).

In many LMICs, including Ghana, reliable patient-level surveillance data on confirmed HFAIs remain limited. As a result, infection-prevention readiness serves as a practical and evidence-based proxy for infection risk by reflecting the structural and organisational capacity of facilities to prevent infections before they occur (World Health Organization & UNICEF Joint Monitoring Programme, 2019).

Although previous studies have examined isolated determinants of HFAIs, few studies have used multilevel modelling to simultaneously assess facility-level, environmental, and organisational factors

while accounting for clustering of facilities within districts. This study therefore examined the multilevel determinants of infection-prevention readiness in health facilities in Ghana using nationally available facility-level data.

2. Patients and Methods

2.1. Type, Period, and Study Population

This study employed a cross-sectional analytical design using secondary data obtained from the national Emergency Obstetric and Newborn Care (EmONC) assessment dataset in Ghana. The study population consisted of acute-care health facilities providing maternal and newborn care services across multiple districts in Ghana.

A total of 300 health facilities with complete infection-prevention readiness indicators and valid district identifiers were included in the final analysis. Facilities with missing key variables or incomplete district-level identifiers were excluded from the multilevel modelling.

The health facility constituted the unit of analysis.

2.2. Data Collection Tools and Techniques

Data were extracted from the national EmONC assessment database using a structured facility-level dataset. Variables included infrastructure indicators, WASH conditions, sanitation facilities, electricity supply, newborn service readiness, and organisational readiness indicators.

The outcome variable was the Infection-Prevention Readiness Index (IPRI), constructed as a composite score from validated indicators reflecting the structural and organisational capacity of facilities to prevent healthcare-associated infections.

The index included:

- Availability of running water
- Functional sanitation facilities
- Electricity supply
- Functional toilets for staff
- Running water in delivery rooms
- Waste management systems
- Availability of 24-hour newborn services
- Essential service readiness indicators

Higher scores indicated better infection-prevention readiness.

Independent variables were grouped into:

Facility-Level Characteristics

- Facility type
- Ownership status
- Electricity availability
- Structural readiness indicators

Environmental Determinants

- Running water availability
- Staff toilet functionality
- Delivery room water supply
- WASH infrastructure

Organisational and Service-Delivery Factors

- Internet access
- 24-hour newborn services
- Service continuity indicators
- Organisational readiness measures

2.3. Data Entry and Analysis

Data were entered and cleaned using Microsoft Excel and analysed using IBM SPSS version 26 for descriptive statistics and R software for multilevel modelling. Quantitative variables were summarized using means and standard deviations where appropriate, while qualitative variables were described using frequencies and percentages. Multilevel linear regression modelling was performed to account for the hierarchical structure of the data, with facilities nested within districts.

Five models were estimated:

1. Null model (random intercept only)
2. Facility-level model
3. Environmental model
4. Organisational model
5. Full combined model

The intraclass correlation coefficient (ICC) was calculated from the null model to determine the proportion of variance attributable to district-level clustering.

Statistical significance was set at $p < 0.05$.

2.4. Ethical Considerations

Ethical approval

for the use of secondary facility-level data was obtained in accordance with institutional requirements. Since anonymised secondary data were used, no direct patient contact occurred, and confidentiality was maintained throughout the study.

3. Results

3.1. Facility Characteristics

A total of 300 health facilities were included in the analysis. Public facilities constituted the majority of the sample, with district hospitals, health centres, and maternity units forming a substantial proportion.

Most facilities had access to electricity supply, although consistency and reliability varied considerably across districts. Ownership status varied between public, private, and faith-based institutions. Table 1 presents the descriptive statistics for facility characteristics.

Table 1
Descriptive Statistics for Facility Characteristics (n = 300)

Variable	Frequency	Percentage (%)
Public ownership	198	66.0
Private ownership	72	24.0
Faith-based ownership	30	10.0
Stable electricity supply	241	80.3
Functional delivery rooms	258	86.0
Availability of newborn services	221	73.7

3.2. Environmental Conditions

Environmental and WASH conditions varied considerably across facilities. Access to running water in delivery rooms was inconsistent, and some facilities lacked functional sanitation systems and adequate toilets for staff.

Functional toilets for staff and continuous water supply were strongly associated with better infection-prevention readiness. Table 2 presents the environmental conditions statistics.

Table 2
Environmental Conditions Statistics

Variable	Frequency	Percentage (%)
Running water in delivery rooms	212	70.7
Functional toilets for staff	195	65.0
Waste management systems available	234	78.0
Reliable sanitation systems	208	69.3

3.3. Organisational and Service-Delivery Factors

Availability of 24-hour newborn services differed across facilities and reflected broader institutional readiness. Internet access was available in some facilities but remained inadequate in others.

Table 3 shows organisational and service-delivery factors.

Table 3
Organisational and Service-Delivery Factors

Variable	Frequency	Percentage (%)
24-hour newborn services	221	73.7
Internet access available	164	54.7
Continuous service delivery systems	210	70.0

3.4. Multilevel Analysis

The null model was estimated to determine district-level clustering.

The model showed significant clustering of infection-prevention readiness at the district level with an ICC of 14.2%, indicating that approximately 14.2% of total variation was attributable to district-level differences. This justified the use of multilevel linear regression. Environmental determinants emerged as the strongest predictors of readiness. Table 4 presents the full multilevel model.

Table 4
Full Multilevel Model Predicting Infection-Prevention Readiness

Predictor	β Coefficient	p-value
Functional toilets for staff	0.2209	< 0.001
Running water in delivery rooms	0.3918	< 0.001
24-hour newborn services	0.1975	< 0.001
Internet access	0.0412	0.182
Stable electricity supply	0.0824	0.061

3.5. Full Model Interpretation

Running water in delivery rooms showed the strongest positive association with infection-prevention readiness (β = 0.3918, p < 0.001), followed by functional toilets for staff and availability of 24-hour newborn services. Internet access showed weaker associations and became statistically non-significant after adjustment.

The inclusion of environmental and organisational predictors substantially reduced between-district variance, indicating that much of the contextual variation across districts was explained by observable facility-level infrastructure.

4. Discussion

This study examined the multilevel determinants of infection-prevention readiness in health facilities in Ghana using nationally available facility-level data and multilevel linear modelling. The findings demonstrate that infection-prevention readiness is shaped by interacting facility-level, environmental, and organisational determinants, with environmental and WASH-related factors emerging as the strongest predictors.

4.1. Facility Characteristics

The study found that structural facility characteristics such as electricity supply, ownership status, and facility readiness were associated with infection-prevention performance, although their effects were weaker compared to environmental determinants in the final adjusted model.

Reliable electricity supply remains essential for infection prevention because sterilisation processes, refrigeration, communication systems, lighting, and continuity of emergency obstetric and newborn services depend on stable power supply. Facilities with unstable electricity may experience disruptions in service delivery that compromise IPC compliance. Similar findings have been reported in WHO guidelines on core components of IPC programmes, where infrastructure and point-of-care readiness are considered fundamental to infection prevention (World Health Organization, 2016).

However, electricity alone was not sufficient to guarantee higher readiness when water systems and sanitation services were inadequate. This supports the argument that infection prevention should be understood as an integrated system rather than isolated infrastructural inputs (Storr et al., 2017).

4.2. Environmental Determinants

Environmental and WASH-related factors were the strongest predictors of infection-prevention readiness. Running water in delivery rooms showed the largest positive effect, followed by functional toilets for staff and sanitation infrastructure.

This finding is consistent with WHO and UNICEF global reports showing that lack of water, sanitation, hygiene services, and environmental cleaning remains one of the strongest barriers to safe healthcare delivery, especially in LMICs (World Health Organization & UNICEF Joint Monitoring Programme, 2019; World Health Organization & UNICEF, 2021). Without reliable access to water and sanitation, healthcare workers cannot consistently practice hand hygiene, environmental cleaning becomes inadequate, and waste management systems fail, increasing the risk of healthcare-associated infections.

The finding also aligns with previous studies in Ghana where poor WASH conditions were identified as major contributors to infection risk and weak IPC implementation (Oppong et al., 2020; WaterAid/World Bank, 2024). The strong effect of running water in delivery rooms is particularly important because maternity and newborn care areas represent high-risk environments for infection transmission.

These results indicate that behavioural interventions alone such as handwashing campaigns may be insufficient when the physical infrastructure required for safe practice is absent.

4.3. Organisational and Service-Delivery Factors

Availability of 24-hour newborn services was significantly associated with better infection-prevention readiness, suggesting that service continuity reflects broader institutional preparedness.

Facilities capable of maintaining continuous newborn services are likely to possess stronger staffing arrangements, better supervision systems, improved emergency readiness, and stronger administrative coordination. These characteristics indirectly strengthen infection prevention systems by ensuring consistency of care and rapid response capacity. Adequate staffing is also fundamental for effective infection prevention because workforce shortages may compromise adherence to infection prevention practices (Shang et al., 2019).

Internet access showed weaker effects and became statistically non-significant after adjustment. This suggests that administrative tools and communication systems are less influential than direct environmental readiness factors when predicting infection-prevention performance.

This finding supports previous evidence that organisational systems matter most when they translate into practical frontline readiness rather than documentation alone (Braun et al., 2020; World Health Organization, 2016).

4.4. District-Level Clustering and Multilevel Interpretation

The null model showed significant district-level clustering of infection-prevention readiness with an ICC of 14.2%, indicating that facility performance is influenced by broader contextual factors beyond individual facility characteristics.

This finding supports ecological systems theory and systems theory, which explain that healthcare outcomes are shaped by nested environments rather than isolated institutions (Bronfenbrenner, 1979; von Bertalanffy, 1968). District-level differences may reflect variation in supervision intensity, infrastructure financing, leadership capacity, policy implementation, and resource allocation.

The full model substantially reduced between-district variance, suggesting that much of the contextual variation across Ghana can be explained by measurable infrastructure and service-readiness indicators rather than unexplained random differences.

This is important for policy because it shows that disparities in infection prevention are largely modifiable through targeted infrastructural and organisational investments.

4.5. Policy Implications

The findings strongly suggest that WASH strengthening should be treated as a central infection prevention strategy rather than a separate development intervention.

Improving water availability, sanitation systems, waste management infrastructure, and continuity of newborn services may produce larger gains in infection prevention than isolated training programmes alone. National IPC policies should therefore integrate WASH financing, infrastructure maintenance, and routine facility readiness monitoring into broader health system strengthening strategies.

Given the estimated economic burden of HFAIs in Ghana, investments in WASH and structural readiness are likely to be both clinically beneficial and cost-saving.

4.6. Study Limitations

This study has several limitations. First, the cross-sectional design limits causal inference. Although significant associations were identified, temporal relationships between predictors and infection-prevention readiness cannot be conclusively established.

Second, the study relied on secondary facility-level data, and some indicators may be affected by under-reporting or measurement errors, particularly in facilities with weaker documentation systems.

Third, facilities with incomplete readiness indicators were excluded from the multilevel analysis, which may introduce selection bias.

Finally, behavioural factors such as healthcare worker compliance, patient-level risk factors, and microbial environmental load were not captured in the dataset. These unmeasured factors may also

influence infection risk.

Despite these limitations, the study provides important nationally relevant evidence on structural determinants of infection prevention and offers strong policy guidance for improving patient safety in Ghana.

5. Conclusion

This study demonstrates that infection-prevention readiness in Ghanaian health facilities is shaped by multilevel determinants operating across facility, environmental, and organisational domains.

Environmental determinants, particularly running water in delivery rooms, functional toilets for staff, and sanitation infrastructure, emerged as the strongest predictors of readiness. Organisational service continuity, especially the availability of 24-hour newborn services, also significantly improved infection-prevention performance.

District-level clustering further revealed that broader contextual influences shape facility readiness, reinforcing the need for multilevel policy approaches.

The findings indicate that improving infection prevention requires more than behavioural compliance or isolated training interventions. Sustainable improvement depends on investments in infrastructure, WASH systems, service continuity, and supportive organisational environments.

Strengthening infection-prevention readiness should therefore be treated as a core health system priority for improving patient safety, reducing healthcare-associated infections, and lowering avoidable healthcare costs in Ghana.

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Abbreviations

ICC; Intraclass correlation coefficient

EmONC; Emergency Obstetric and Newborn Care

IPRI; Infection-Prevention Readiness Index

IPC; Infection prevention and control

WASH; Water, sanitation and hygiene

HFAI; Health-facility-associated infection

HAI; Healthcare-associated infection

Declarations

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Authors' contributions

M.I. conceived and designed the study, conducted the analysis, interpreted the results, and drafted and revised the manuscript. The author read and approved the final manuscript.

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Competing Interests

The author declares no competing interests regarding the publication of this paper.

Availability of data and materials

The datasets analysed during the current study are available from the corresponding author on reasonable request, subject to applicable permissions and data access restrictions.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Ethical approval for the use of secondary facility-level data was obtained in accordance with institutional requirements. Since anonymised secondary data were used, no direct patient contact occurred, and confidentiality was maintained throughout the study.

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