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Feasibility, accessibility, and compliance with World Health Organisation– recommended hand hygiene practices among healthcare workers in a neonatal unit of a teaching hospital in Ebonyi- State, Nigeria

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Abstract

Background

Hand hygiene is central to infection prevention in neonatal care because newborns, especially preterm or critically ill infants, have immature immunity and frequent invasive procedures, making them highly vulnerable to healthcare-associated infections However, while adherence to the World Health Organisation (WHO) Five Moments is effective, sustaining it in resource-constrained settings is challenging, and integrated evidence linking observed practice, enabling infrastructure, and behavioural determinants in lower middle-income countries (LMIC) neonatal units remains limited.

Methods

A convergent mixed-methods design was conducted in a neonatal unit of a tertiary hospital in a LMIC. Infrastructure assessment covered eight hand hygiene stations. Direct observation recorded 269 hand hygiene opportunities across 90 sessions, with compliance defined as alcohol-based hand rub (ABHR) or soap-and-water action at indicated WHO moments. Session-level compliance (HHCO/THOO) was analysed using chi-square tests and binomial generalized linear models (GLM). Logistic regression examined predictors of any missed opportunity per session. Semi-structured interviews were analysed thematically and interpreted using COM-B and Health Belief Model (HBM) frameworks.

Results

All eight handwashing stations were present, but only 5/8 (62.5%) were functional; running water was available at 2/8 (25.0%), soap at 2/8 (25.0%), ABHR at 4/8 (50.0%), and no drying facilities were available. Overall compliance was 94.8% (255/269 opportunities), with lower adherence before touching a patient (91.8%) and before aseptic procedures (91.1%) compared with after-contact moments (97.1–100.0%). Most sessions (74/90; 82.2%) showed perfect compliance. Compliance did not differ significantly between Unit 1 (NICU/ICU; 96.7%) and Unit 2 (newborn ward; 93.9%) (χ^2 p=0.869). In GLM analyses, neither unit (OR=0.53, 95% CI 0.07–4.34) nor session duration (OR per 10 minutes=0.98, 95% CI 0.70–1.36) predicted compliance. Qualitative findings revealed strong moral commitment and peer accountability but highlighted infrastructure instability and workload pressures as key barriers.

Conclusions

High observed WHO Five Moments compliance coexisted with weak enabling infrastructure, suggesting reliance on behavioural adaptation and strong local norms rather than resilient system support. Sustained neonatal infection prevention requires aligning staff motivation with reliable water, soap, drying capacity, and point-of-care ABHR

placement, as well as targeting anticipatory *“before”* moments supported by organisational systems that reduce structural barriers.

Keywords: Hand hygiene compliance; WHO Five Moments; Neonatal intensive care unit; Infection prevention and control; Low-resource settings.

INTRODUCTION

Background of the study;

Healthcare-associated infections remain a major threat to neonatal survival, particularly in resource-constrained settings where fragile newborns are exposed to invasive procedures and high-contact care [1,2]. Globally, an estimated 2.3 million neonatal deaths occur each year, with the burden highest in sub-Saharan Africa [3,4]. Antimicrobial resistance further complicates neonatal sepsis management and increases the consequences of preventable transmission in hospital settings [5]. In this context, strengthening infection prevention and control (IPC) especially hand hygiene remains a critical and pragmatic patient-safety priority [6,7].

The World Health Organization's "Five Moments for Hand Hygiene" provides a standardized behavioural framework to interrupt pathogen transmission at key points of patient care, and improvements in hand hygiene have been consistently linked to reduced healthcare-associated infections when implemented with adequate system support [6,7]. However, neonatal units pose particular challenges: care is time-sensitive, contact frequency is high, and hand hygiene depends on reliable access to sinks, running water, soap, drying materials, and alcohol-based hand rub (ABHR) [6,8,9,10]. Hand hygiene is a cornerstone of IPC and is strongly associated with reductions in healthcare-associated infection risk when implemented reliably [6,7,11]. The WHO "My Five Moments for Hand Hygiene" framework operationalizes hand hygiene at key patient-care transition points to reduce transmission in clinical settings [6]. In neonatal care specifically, evidence shows that effective hand hygiene promotion can reduce healthcare-associated infection risk

among neonates, supporting the clinical relevance of monitoring moment-specific adherence in NICU contexts [8].

Despite the centrality of hand hygiene, consistent performance in resource-constrained neonatal settings is often undermined by infrastructure and workflow realities, including unreliable running water, inconsistent soap/ABHR supply, and high workload intensity [6,9,10]. Evidence from neonatal units in Nigeria, including state-level and facility-specific contexts such as Ebonyi State, remains limited on how well the Five Moments can be carried out in everyday practice when infrastructure and supply chains are inconsistent. This gap matters because hand hygiene performance is not only a function of knowledge and intention, but also of whether the care environment supports rapid, repeated hygiene actions at the point of care [6,11].

To address the common concern that “feasibility” may imply longitudinal implementation testing, this study uses feasibility in a practical/perceived sense i.e., the perceived ability to perform the Five Moments within routine workflow given available resources. Accessibility refers to the consistent point-of-care availability and functionality of required infrastructure and consumables, and compliance refers to the observed performance of a hand hygiene action at indicated moments (ABHR or soap-and-water, per WHO guidance) [6,11]. As a result, understanding hand hygiene as a “system-enabled” practice rather than solely an individual behavior is essential for interpreting compliance patterns and designing interventions that can be sustained beyond observation periods. Importantly, evidence from neonatal units in Nigeria remains limited regarding how

practical feasibility, accessibility, and observed compliance co-exist and interact within real-world constraints [6, 11, 12].

In this study, we operationalised these constructs as follows: feasibility refers to perceived/practical ability to perform the Five Moments within routine workflow given available resources; accessibility refers to consistent point-of-care availability and functionality of infrastructure and supplies; and compliance refers to observed performance of a hand hygiene action (ABHR or soap-and-water) at indicated moments [6]. We used a convergent mixed-methods approach to quantify moment-specific compliance and enabling infrastructure while also explaining observed patterns through healthcare workers' accounts of everyday practice realities.

Guided by COM-B and Health Belief Model (HBM) as interpretive lenses, we framed hand hygiene as a behavior shaped by capability (knowledge and skills), opportunity (infrastructure/supplies and time), and motivation (professional norms, perceived risk, and moral commitment), alongside perceived susceptibility/severity, benefits/barriers, and cues to action. Accordingly, capability and risk perceptions were explored in interviews, opportunity was assessed through infrastructure audit and service-area context, and motivation/cues were examined through unit culture and accountability narratives [13,14]. This study therefore aimed to: (1) determine the practical feasibility of the WHO Five Moments among neonatal-unit healthcare workers; (2) examine accessibility of WHO-recommended hand hygiene resources; (3) determine moment-specific compliance; (4) explore barriers and facilitators shaping consistent practice; and

(5) examine associations between infrastructure context (service area proxy) and compliance patterns.

METHODS

Study design

This study employed a convergent mixed-methods design, integrating direct structured observation, facility-level infrastructure assessment, and semi-structured qualitative interviews to examine the feasibility, accessibility, compliance, and contextual determinants of the World Health Organization (WHO) Five Moments for Hand Hygiene among healthcare workers (HCWs) in a neonatal unit. Quantitative and qualitative data were collected concurrently, analysed separately, and integrated during interpretation to enable triangulation and a comprehensive understanding of hand hygiene practice [15].

Study setting

The study was conducted in the neonatal services of Alex Ekwueme University Federal Teaching Hospital - a tertiary healthcare facility in Ebonyi State, Nigeria. The neonatal services comprise two distinct service areas: the neonatal intensive care unit (NICU/ICU; Unit 1) and the newborn/neonatal ward (Unit 2). These units differ in patient acuity, staffing patterns, workflow intensity, and proximity to hand hygiene infrastructure. For analytic purposes, service area was used as a proxy indicator of differential infrastructure access.

Study population

The study population comprised healthcare workers routinely involved in neonatal care, including nurses, doctors, and trainee staff. HCWs were eligible for quantitative observation if they were actively providing patient care during observation periods. For

the qualitative component, HCWs with at least six months' experience in the neonatal unit were purposively sampled to capture a range of professional roles and experiences.

Quantitative data collection

Hand hygiene observation

Hand hygiene compliance was assessed using direct, structured observation guided by the World Health Organization (WHO) Five Moments for Hand Hygiene framework [6]. Observations were conducted during routine clinical activities across 90 discrete observation sessions, yielding a total of 269 observed hand hygiene opportunities. Each opportunity was classified according to the WHO Five Moments, namely: before touching a patient, before a clean or aseptic procedure, after body fluid exposure risk, after touching a patient, and after touching patient surroundings. For each observed opportunity, the corresponding hand hygiene action was recorded as handwashing with soap and water, use of alcohol-based hand rub (ABHR), missed opportunity, or glove use. In accordance with WHO guidance, a hand hygiene action was considered compliant if either ABHR or soap-and-water was performed [6]. However, when hands were visibly soiled, compliance was defined strictly as handwashing with soap and water.

Session-level aggregation

Observation data were aggregated at the session level to derive summary measures for analysis. For each observation session, the total number of hand hygiene opportunities observed (THOO), the total number of compliant actions observed (HHCO), and the total number of missed opportunities (HHONC), calculated as THOO minus HHCO, were recorded. Additional session-level variables included session duration, measured in

minutes, and service area, classified as Unit 1 (NICU/ICU) or Unit 2 (newborn/neonatal ward). Session-level compliance was calculated as the proportion of compliant actions per session (HHCO/THOO).

Infrastructure assessment

A structured infection prevention and control (IPC) infrastructure audit was conducted concurrently with hand hygiene observations to assess the availability and functionality of hand hygiene resources within the neonatal service areas. The audit evaluated the presence and functionality of handwashing sinks, availability of running water, soap, and alcohol-based hand rub, availability of hand-drying facilities, presence of hand hygiene posters, and the condition of sink drainage. Eight designated hand hygiene stations were assessed. Functionality reflected whether a station was structurally usable at the time of assessment, while point-of-care adequacy reflected the reliable availability of supplies during routine clinical care [6].

Qualitative data collection

Semi-structured interviews were conducted with purposively selected healthcare workers using an interview guide informed by the WHO Five Moments for Hand Hygiene framework and behaviour change theory. Interviews explored participants' knowledge and understanding of the Five Moments, perceived feasibility and accessibility of hand hygiene, barriers and facilitators to consistent practice, unit culture, workload, and broader systemic influences, as well as suggested strategies for improving hand hygiene implementation. Interviews were conducted in private hospital spaces to ensure

confidentiality, audio-recorded with participant consent, transcribed verbatim, and anonymised prior to analysis. Sampling continued until thematic saturation was achieved.

Study outcomes and operational definitions

The primary quantitative outcome was hand hygiene compliance, assessed through direct observation using the WHO Five Moments framework. Compliance was measured at two levels: the opportunity level, defined as the proportion of compliant hand hygiene actions performed out of total opportunities for each WHO moment, and the session level, defined as the proportion of compliant actions per observation session (HHCO/THOO). Secondary quantitative outcomes included the availability and functionality of hand hygiene infrastructure, assessed through the structured facility audit, and service area (Unit), which was used as a proxy indicator of differential access to hand hygiene resources. Qualitative outcomes included healthcare workers' perceptions of the feasibility of performing the WHO Five Moments, accessibility of hand hygiene resources, barriers and facilitators influencing consistent hand hygiene practice, and suggested strategies for improving implementation within the neonatal unit.

Data analysis

Quantitative analysis

Descriptive statistics were used to summarise hand hygiene opportunities, observed actions, compliance rates, and infrastructure indicators. Associations between hand hygiene compliance, service area, and session duration were examined using chi-square or Fisher's exact tests, as appropriate. Binomial generalized linear models were fitted with

HHCO specified as successes and THOO as trials, and logistic regression models were used to examine the occurrence of one or more missed hand hygiene opportunities per session. Results were reported as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$, and findings were interpreted cautiously in light of the low frequency of non-compliant events.

Qualitative analysis

Qualitative data were analysed using thematic analysis [16]. This process involved data familiarisation, systematic coding, theme development, and refinement. Themes were organised to reflect feasibility, accessibility, compliance context, barriers, facilitators, and proposed improvement strategies. Verbatim quotations were used in the Results section to illustrate key themes and enhance analytic credibility.

Integration of quantitative and qualitative findings

Quantitative and qualitative findings were integrated during the interpretation phase. Qualitative insights were used to contextualise observed compliance patterns, service-area differences, and infrastructure constraints identified through quantitative analyses, thereby enabling a more comprehensive understanding of hand hygiene practice within the neonatal unit.

Theoretical framework

Interpretation of findings was guided by the Capability–Opportunity–Motivation–Behaviour (COM-B) model and the Health Belief Model (HBM). These frameworks

informed understanding of how healthcare workers' knowledge and skills (capability), environmental and organisational factors (opportunity), motivational processes, perceived risk, perceived benefits and barriers, and cues to action interacted to influence hand hygiene behaviour in the neonatal setting [13,14].

Ethical considerations

Ethical approval for this study was obtained from the Health Research Ethics Committee of Alex Ekwueme Federal University Teaching Hospital, Abakaliki (AEFUTHA-HREC; NHREC/16/06/25/539). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all interview participants prior to data collection. Observational data were collected without recording personal identifiers, and all quantitative and qualitative data were anonymised prior to analysis to ensure confidentiality and data protection.

RESULTS

A total of eight healthcare workers participated in the qualitative interviews, and 90 hand hygiene observation sessions were completed for the quantitative component, generating 269 WHO Five Moments opportunities. Participants represented frontline staff involved in routine neonatal care delivery. The observation sessions were conducted across the NICU/ICU area (Unit 1) and the newborn/neonatal ward (Unit 2), although unit information was missing for 25 sessions. Overall, the Results are presented according to the five study objectives, integrating infrastructure assessment, direct observation, and interview findings.

Participant Characteristics

Table 1A summarises the characteristics of the 50 healthcare workers included in the study. Most participants were nurses (36/50; 72.0%), while doctors accounted for 28.0% (14/50). The majority had 1–10 years of service (32/50; 64.0%), with 22.0% (11/50) reporting 11–20 years and 14.0% (7/50) reporting ≥21 years. Female participants comprised 68.0% (34/50) of the sample. All participants had tertiary-level education

Table 1A. Characteristics of healthcare workers (n = 50)

Characteristic	Category	n (%)
Professional role	Nurses	36 (72.0)
	Doctors	14 (28.0)
Years in service	1–10 years	32 (64.0)
	11–20 years	11 (22.0)
	≥21 years	7 (14.0)
Gender	Female	34 (68.0)

Characteristic	Category	n (%)
	Male	16 (32.0)

Footnote: All participants had tertiary-level education.

A total of 50 healthcare workers participated in the study. The majority were nurses (36/50; 72.0%), while doctors accounted for 14 (28.0%). Most participants had between 1 and 10 years of clinical experience (32/50; 64.0%), with smaller proportions reporting 11–20 years (22.0%) or ≥21 years (14.0%) of service. Females constituted 68.0% of the sample. All participants had attained tertiary education.

Feasibility of the WHO Five Moments of hand hygiene among healthcare workers

Qualitative findings indicate that the WHO Five Moments for Hand Hygiene were perceived as feasible in principle by healthcare workers in the neonatal unit. Participants expressed an intention to perform hand hygiene as part of routine care ("Yeah, we practice it" (P1)). However, feasibility was frequently conditional on enabling conditions particularly the availability of basic resources such as water ("sometimes we have some constraints… we may not have water" (P8)) and was further shaped by the practical realities of delivering care in a busy neonatal setting. Overall, these accounts suggest that feasibility was not determined solely by knowledge or motivation, but by whether the clinical environment and workflow practically allowed healthcare workers to perform the Five Moments during routine care delivery. Additional qualitative themes underpinning feasibility and practice are summarised in Table 1B.

Table 1B: Summary of Qualitative Themes on Hand Hygiene Practice

Theme	Key findings
Knowledge of WHO Five Moments	Awareness present but fragmented; recall often situational rather than structured
Feasibility	Perceived as achievable in principle but dependent on enabling conditions
Accessibility	Constrained by inconsistent water supply, soap, ABHR, and delayed repairs

Theme	Key findings
Cultural facilitators	Strong moral framing and peer accountability within neonatal unit
Barriers	Infrastructure fragility, workload pressure, fatigue, time constraints
Suggested improvements	Reliable supplies, functional infrastructure, monitoring, education, supervision

Footnote: *Themes were derived from thematic analysis of semi-structured interviews and are supported by verbatim quotations presented in the Results text.*

Examine the accessibility of WHO-recommended hand hygiene care among HCWs in the neonatal unit

Infrastructure assessment indicated limited point-of-care accessibility to essential hand hygiene resources. Although handwashing sink stations were present (8/8; 100.0%), only 5/8 (62.5%) were functional, and running water was available at 2/8 (25.0%) stations. Soap was available at 2/8 (25.0%) stations and ABHR at 4/8 (50.0%), while drying facilities were absent (0/8; 0.0%) (Table 2), running water availability was limited and concentrated in specific service areas, indicating uneven point-of-care access across the unit. Additional enabling conditions were incomplete, with hand hygiene posters present at 4/8 (50.0%) service points and sinks with good drainage present at 4/8 (50.0%), of which 2/4 (50.0%) were functional (Table 2). Interview accounts reinforced that "accessibility" was understood as continuous functionality and sustained supply rather than mere presence of materials; participants emphasised instability over time ("management should put in more… so that… it will not be for a short time, but for a while" (P8)) and variable access to ABHR ("I have not seen any of them sanitize here" (P2)), indicating that point-of-care availability was inconsistent. Overall, both the infrastructure audit and interviews indicate that access was constrained by unreliable supplies and limited functional point-of-care resources.

Table 2: Infection Prevention and Control Infrastructure Assessment (Hand hygiene stations and supplies)

Infrastructure indicator	Present (n/N, %)	Functional (n/N, %)	Point-of-care / Adequate supply
Handwashing sink stations	8/8 (100.0)	5/8 (62.5)	Limited
Soap available	2/8 (25.0)	—	No (inconsistent/insufficient)
Alcohol-based hand rub (ABHR) available	4/8 (50.0)	—	Limited
Hand hygiene posters present	4/8 (50.0)*	—	Limited (partial coverage)
Drying facilities available	0/8 (0.0)	—	No
Sinks with good drainage	4/8 (50.0)	2/4 (50.0)	Limited
Water available at station	2/8 (25.0)	—	No (not reliably available)

Footnotes: **Posters were counted across service points; denominator expressed using the 8-station framework for consistency*.

A *"hand hygiene station"* refers to a designated sink point used for handwashing within neonatal service areas. *"Functional"* indicates a station was structurally usable at the time of assessment; however, running water was available at only 2/8 stations, limiting effective point-of-care handwashing even where sinks exist. Overall, enabling hand hygiene infrastructure was suboptimal, driven by limited soap coverage, absent drying facilities, and running water available at only a minority of sink stations.

Determine compliance with the WHO Five Moments of hand hygiene among HCWs in the neonatal unit

Direct observation identified 269 hand hygiene opportunities, with 255 compliant actions performed, yielding an overall compliance of 94.8%, and 14 missed opportunities (Table 3). Compliance varied across WHO moments, with the lowest adherence observed before touching a patient (78/85; 91.8%, 7 missed) and before aseptic procedure (41/45; 91.1%,

4 missed), while compliance was highest after body fluid exposure risk (30/30; 100.0%, 0 missed) and remained high after touching a patient (73/75; 97.3%, 2 missed) and after touching patient surroundings (33/34; 97.1%, 1 missed) (Table 3). This is captured in the bar chart showing the percentage compliance for each WHO Five Moment based on direct observation (N = 269 opportunities) (Figure 1) Compliance was lowest for moments occurring before patient contact and before aseptic procedures, and highest for the post-exposure and post-contact moments. At the session level (n = 90), most observation sessions (76/90; 84.4%) recorded perfect compliance (3 opportunities; 3 actions; 0 missed), while 14/90 (15.6%) sessions recorded one missed opportunity (Table 4). Compliance estimates were interpreted alongside infrastructure constraints (Table 2), recognising that supplies and station functionality varied across service areas.

Table 3: Compliance with WHO Five Moments for Hand Hygiene (Direct observation; N = 269 opportunities)

WHO Five Moment	Opportunities (n)	Actions performed (n)	Missed (n)	Compliance (%)
Before touching a patient	85	78	7	91.8
Before aseptic procedure	45	41	4	91.1
After body fluid exposure risk	30	30	0	100.0
After touching a patient	75	73	2	97.3
After touching patient surroundings	34	33	1	97.1
Total	**269**	**255**	**14**	**94.8**

Footnote: *Hand hygiene action was defined as either alcohol-based hand rub (ABHR) or soap-and-water and was recorded as compliant for all Five Moments in line with WHO guidance, except when hands were visibly soiled (soap-and-water required).*

Compliance estimates were based on direct observation and interpreted alongside infrastructure constraints (Table 2), recognising variation in station functionality and

supplies across service areas; corresponding raw compliance counts are presented in Table 3. Observation session characteristics are summarised in Table 5.

Table 4: Distribution of Hand Hygiene Opportunities Actions, and Missed Opportunities per Observation Session (n = 90 sessions)

Per-session pattern	Sessions (n)	Percentage (%)
3 opportunities; 3 actions; 0 missed	74	82.2
3 opportunities; 2 actions; 1 missed	14	15.6
2 opportunities; 2 actions; 0 missed	1	1.1
1 opportunity; 1 action; 0 missed	1	1.1
Total	**90**	**100.0**

Footnote: *Per-session counts reflect aggregated observation summaries. Total missed opportunities across all sessions sum to 14, consistent with Table 3 totals (269 opportunities − 255 actions = 14).*

Table 5: Characteristics of Hand Hygiene Observation Sessions (n = 90)

Characteristic	Value
Total observation sessions	90
Sessions with unit recorded	65
Unit 1 (NICU/ICU), n (%)	30 (46.2%)
Unit 2 (Newborn/neonatal ward), n (%)	35 (53.8%)
Sessions without unit recorded	25
Median session duration (minutes)	45 (30–50)
minutes; mean ± SD:	44.0 ± 16.2)
Sessions with ≥1 missed opportunity	14 (15.6%)
Sessions with perfect compliance	76 (84.4%)

Footnote: *Unit 1 refers to the NICU/ICU area and Unit 2 refers to the newborn/neonatal ward. Session duration reflects the total observation time per session as recorded by observers. Unit information was unavailable for 25 sessions.*

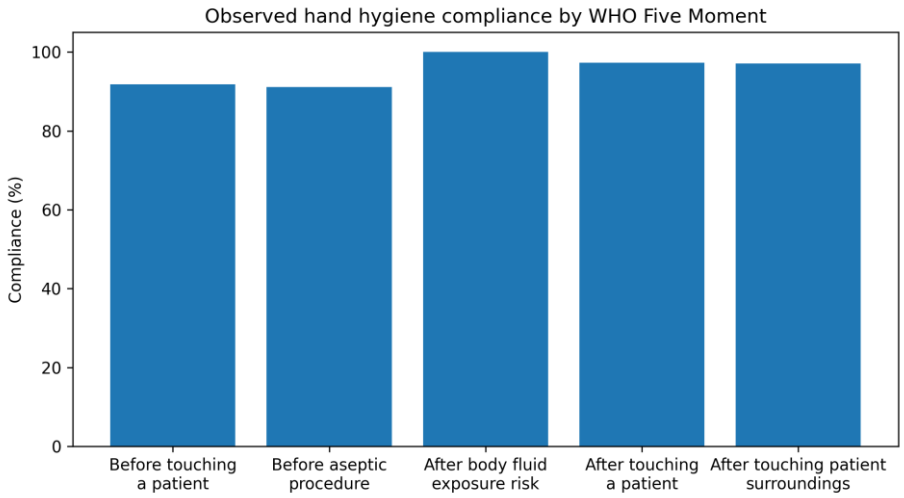


Figure 1. Observed hand hygiene compliance by WHO Five Moments.

Explore barriers and facilitators influencing consistent Five Moments practice among HCWs in neonatal units

Qualitative findings identified a set of interacting facilitators and barriers shaping consistent Five Moments practice in the neonatal unit. Facilitators included a strong moral commitment to neonatal safety and a unit culture of peer accountability**,** where hand hygiene was framed as essential to protecting vulnerable newborns ("*prevent infections to the babies*" (P7)) and reinforced through socially enforced norms ("*If you don't wash your hand you are a murderer*" (P7)). However, several barriers undermined consistent practice. Knowledge of the Five Moments was foundational but uneven**,** with fragmented recall and hesitancy suggesting partial internalisation (e.g., "*I know there are five steps… Before contact, after contact…*" (P2); "*I will try to mention it… before you meet a patient…*" (P1)). Participants also described resource instability and infrastructure fragility as major constraints on practice, emphasising that functional supplies and facilities were not reliably available over time ("*management should put in more… so that… it will not be for a short time, but for a while*" (P8); "*to repair… might take a longer time*" (P7)).

Workload-related pressures and fatigue further contributed to lapses, particularly during busy periods ("*they might be tired*" (P1); "*once in a while it may just overlook*" (P7)). Consistent with these barriers, participants' improvement suggestions focused predominantly on system-level interventions; reliable water/supplies, timely repairs, monitoring mechanisms, education, and supportive supervision ("*there should be… some monitoring team… to ensure… equipment are in order*" (P7); "*tap water is always readily available*" (P6)). Overall, the qualitative findings indicate that hand hygiene performance reflected a motivated workforce operating within structural constraints, with consistency shaped by the balance between strong social/moral facilitators and persistent system and workload barriers.

Session-level association between service area (proxy infrastructure access) and hand hygiene compliance

To examine whether compliance differed by service area (Unit 1 refers to the NICU/ICU area and Unit 2 refers to the newborn ward/neonatal ward) as a proxy for infrastructure variation, session-level models were fitted using aggregated observation data (n = 90 sessions) (Table 7, Figure 2) with compliance expressed as HHCO/THOO (Table 6, Figure 2) restricted to sessions with unit recorded (195/269 opportunities). Because infrastructure indicators were not linked at the opportunity level, service area (Unit) was used as a proxy for differential infrastructure access. Among sessions with unit information available (n = 65), pooled compliance was slightly higher in Unit 1 (29/30; 96.7%) than Unit 2 (155/165; 93.9%), but the difference was not statistically significant (χ^2 test, p = 0.869; Fisher's exact test, p = 1.000). In binomial GLM analyses, unit was not

significantly associated with compliance (OR for Unit 2 vs Unit 1 = 0.53, 95% CI 0.07–4.34; p = 0.558). Session duration was not significantly associated with compliance (OR per 10-minute increase = 0.98, 95% CI 0.70–1.36; p = 0.888), and this remained unchanged after adjustment for unit (p = 0.518). Missed opportunities were uncommon; among sessions with unit recorded, 11/65 sessions contained ≥1 missed opportunity (compared with 14/90 sessions with a missed opportunity in the full dataset; Table 4) (HHONC derived as THOO − HHCO), and logistic regression showed no significant associations with unit (OR = 1.93, 95% CI 0.22–17.13; p = 0.556) or session duration (OR per 10-minute increase = 1.16, 95% CI 0.77–1.74; p = 0.491). Qualitative findings helped contextualise these patterns by indicating that practical access to resources was intermittently constrained, with participants emphasising that supply instability and delays in repairs can limit consistent access *(e.g., "to repair… might take a longer time" (P7)).* Given that unit information was unavailable for 25 sessions and missed events were rare, these models had limited power to detect small differences between areas.

Table 6: Hand Hygiene Compliance by Service Area (Proxy for Infrastructure Access)

Service area	Opportunities (n)	Compliant actions (n)	Compliance (%)
Unit 1 (NICU/ICU)	30	29	96.7
Unit 2 (Newborn/neonatal ward)	165	155	93.9
Total (sessions with unit recorded)	**195**	**184**	**94.4**

Footnote: Compliance is expressed as HHCO/THOO. Service area was used as a proxy for differential infrastructure access because infrastructure indicators were not linked at the opportunity level.

Table 7: Session-level predictors of hand hygiene compliance and missed opportunities (n = 90 sessions)

Model/Outcome	Predictor	Effect estimate	95% CI	p-value
Pooled compliance difference	Unit (Unit 1 vs Unit 2)	χ^2 test	—	0.869
	Unit (Unit 1 vs Unit 2)	Fisher's exact test	—	1.000
Binomial GLM (HHCO/THOO)	Unit (Unit 2 vs Unit 1)	OR = 0.53	0.07–4.34	0.558
Binomial GLM (HHCO/THOO)	Duration (per 10-minute increase)	OR = 0.98	0.70–1.36	0.888
Binomial GLM (adjusted)	Duration + Unit	Unit-adjusted duration effect	—	0.518
Logistic regression (Any miss ≥1)	Unit (Unit 2 vs Unit 1)	OR = 1.93	0.22–17.13	0.556
Logistic regression (Any miss ≥1)	Duration (per 10-minute increase)	OR = 1.16	0.77–1.74	0.491

Footnote: *Unit 1 refers to the NICU/ICU area and Unit 2 refers to the newborn/neonatal ward. Compliance was modelled using a binomial generalized linear model (GLM) with compliant actions (HHCO) as successes and total opportunities observed (THOO) as trials. "Any missed opportunity" was defined as ≥1 missed hand hygiene opportunity per session and analysed using logistic regression. Unit information was available for 65/90 sessions.*

Figure 2 is a forest plot summarising odds ratio (log scale) from the session-level models assessing (i) overall compliance (binomial GLM) and (ii) occurrence of any missed opportunity (logistic regression) as a function of service area (Unit 2 vs Unit 1) and session duration (per 10-minute increase). Error bars represent 95% confidence intervals.

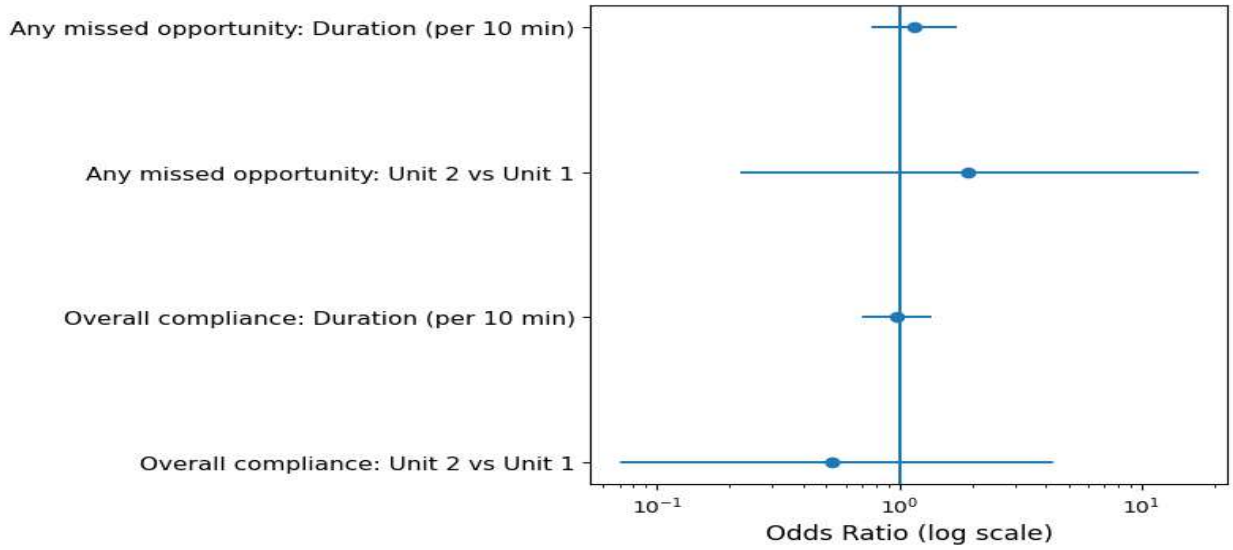


Figure 2. Associations of service area and session duration with compliance outcomes. *Forest plot of odds ratios (log scale) from session-level models assessing (i) overall compliance (binomial GLM) and (ii) occurrence of any missed opportunity (logistic regression) as a function of service area (Unit 2 vs Unit 1) and session duration (per 10-minute increase). Points indicate odds ratios and horizontal bars indicate 95% confidence intervals; the vertical line denotes OR = 1 (no association). Unit 1 = NICU/ICU; Unit 2 = newborn/neonatal ward.*

DISCUSSION

This mixed-methods study found that neonatal-unit healthcare workers perceived the WHO Five Moments for Hand Hygiene as feasible in principle [6] and demonstrated high observed compliance during routine care, despite suboptimal infrastructure and inconsistent point-of-care access to supplies. This gap matters in neonatal care, where delayed or inadequate infection prevention can compound diagnostic and antimicrobial challenges in suspected sepsis [4]. The qualitative strand clarifies that this performance reflects a motivated workforce and strong local safety culture, but that day-to-day consistency remains contingent on system reliability (water, soap, ABHR availability, repairs) and workload realities.

Interpretation of key quantitative findings. The moment-specific pattern is as informative as the overall compliance estimate. Adherence was comparatively lower for *"before*" moments (before touching a patient; before aseptic procedure) than for *"after"* moments (after patient contact; after body fluid exposure risk; after touching patient surroundings). This internal gradient is clinically plausible and aligns with well-documented behavioural patterns in hospital hand hygiene studies, where *"after"* moments tend to show higher adherence than anticipatory *"before"* indications [9,10]. At the session level, the low frequency of missed opportunities and the predominance of perfectly compliant sessions suggest either strong routine performance or limited opportunity variability during the observation windows, both interpretations pointing to the need for cautious inference about *"typical"* performance across all shifts, particularly given the known influence of observation-related reactivity in hand hygiene studies [9].

Mixed-methods integration: explaining the apparent paradox. The apparent tension between high observed hand hygiene compliance and constrained access to water, soap, and drying facilities becomes clearer when the qualitative findings are considered. Participants described persistent reliance on system functioning (availability, continuity of supply, timely repairs) as the difference between being able to execute hand hygiene consistently and having to improvise. Their accounts also indicate that staff may adapt to infrastructure deficits through pragmatic substitution (e.g., ABHR where available), consistent with WHO recommendations that alcohol-based hand rub can compensate for limited sink access when appropriately positioned at point-of-care [6, 7] and workflow workarounds [6,11], a pattern also reported in prior Nigerian hospital work where infrastructure gaps and material placement shaped day-to-day hand hygiene enactment [17]. In this sense, the quantitative findings may represent successful behavioural adaptation under constraints rather than proof that infrastructure is inconsequential. The qualitative data therefore strengthen interpretation by showing *how* compliance can be maintained in the short term, while simultaneously identifying why it may be fragile over time. This integrative insight illustrates the added value of convergent mixed-methods designs in implementation research, where behavioural outcomes and contextual determinants must be interpreted together rather than in isolation [15,18].

Theoretical interpretation (COM-B and HBM). The findings cohere strongly when mapped to COM-B and HBM constructs [13,14]. Under COM-B, *Capability* is present but imperfect: awareness of the Five Moments exists, yet recall can be fragmented, indicating

incomplete internalisation and potential vulnerability in fast-paced tasks. Opportunity is the most structurally constrained domain: limited running water, intermittent soap/ABHR, and absent drying facilities reduce reliable point-of-care enactment even when motivation is high. Motivation appears unusually strong in the neonatal context, reinforced by professional identity, perceived infant vulnerability, and peer accountability. Under the HBM, the neonatal context elevates perceived severity and susceptibility (newborn vulnerability), creating powerful cues to action through unit norms; however, perceived barriers remain high (supply interruptions, repair delays, workload pressure), which can disrupt even highly motivated behaviour. Together, these frameworks suggest that sustained hand hygiene in neonatal units is a system-enabled behaviour shaped by capability, opportunity, and motivation, rather than solely an individual compliance choice [13]

Comparison with existing literature: The study's overall high observed compliance sits at the upper end of what is commonly reported in many hospital hand hygiene studies, particularly in low- and middle-income settings where infrastructural constraints are frequent [9,10,11, 12], although recent neonatal-unit quality improvement initiatives in African contexts have demonstrated that structured, context-sensitive strategies can achieve measurable [18]. Similar Nigerian evidence using a mixed-methods approach reported inadequate hand-hygiene infrastructure and identified inconvenient location of hand-hygiene materials and forgetfulness as common barriers to consistent practice, reinforcing that *"opportunity"* constraints can persist even when staff accept hand hygiene as important [17]. Two features may plausibly explain this divergence without over-

claiming: first, neonatal care often carries heightened perceived risk and documented vulnerability to healthcare-associated infection, where improved hand hygiene has been associated with significant reductions in neonatal infection risk [8]**,** which can elevate motivation and peer enforcement compared with general wards; second, observation-based estimates can be sensitive to reactivity and to the specific distribution of observed indications, time windows, and observer procedures. Importantly, the pattern of relatively lower performance in anticipatory *"before"* moments compared with *"after"* moments is consistent with broader hand hygiene evidence and is a more stable signal than the headline percentage alone. This supports prioritising improvement efforts around "before patient contact" and *"before aseptic procedure,"* even when compliance aggregate appears high. Emerging NICU-based interventions using structured feedback and behavioural cues have shown that even high-performing units can further optimise adherence to critical hand hygiene parameters [20], reinforcing the value of targeted micro-interventions rather than relying solely on overall compliance rates.

Operational implications for practice, policy, and research.

1. *Hospital management/facility leadership***:** Prioritise reliable point-of-care opportunity by ensuring continuous running water, soap provision, and drying facilities where sinks are located; institute a rapid repair pathway for non-functional stations with defined turnaround times and accountability (e.g., maintenance log with escalation). Ensure ABHR availability is not merely present in the unit but positioned at point-of-care for high-contact zones [17].

2. *Neonatal unit leadership (HOD/Matron/Charge nurse) and IPC team***:** Implement targeted quality improvement focusing on the *"before"* moments brief shift-start reminders, visual cues at bedside/procedure areas, and routine audit-and-feedback cycles that report moment-specific adherence (not just overall compliance) [7]. Pair this with supportive supervision rather than punitive messaging to protect morale while maintaining accountability.
3. *Frontline staff***:** Standardise workflow micro-habits that reduce cognitive load e.g., integrating hand hygiene into the sequence of task preparation before patient contact and before aseptic procedures, and clarifying when gloves do not substitute for hand hygiene.
4. *Researchers/quality units***:** In future work, link infrastructure indicators to observed opportunities at the point-of-care (so that "*opportunity*" and "access" are paired in the dataset), extend observation across varied shifts and workload periods, and consider designs that reduce reactivity (while remaining ethical and transparent). Where event rates are low, plan analyses that are robust to rare outcomes and report uncertainty clearly.

Strengths and limitations.

A major strength of this study is the convergent mixed-methods design, which allows findings to move beyond a single compliance estimate to explain determinants of behaviour in context, an approach that is particularly valuable for implementation-oriented infection prevention and control (IPC) research, where integration of quantitative and qualitative strands strengthens interpretive validity and explanatory depth [15,19]. The combined use of infrastructure assessment, direct observation, and interviews improves

interpretive credibility through triangulation. Limitations include the cross-sectional nature of the data (limiting causal inference and long-term sustainability claims), potential behavioural reactivity during observation, and low numbers of missed events, which reduce statistical power to detect small but meaningful differences across service areas or session characteristics. In addition, missing unit labels for a subset of sessions may dilute stratified comparisons and should be acknowledged when interpreting unit-level findings. This study was conducted in a single tertiary teaching hospital, which may limit the generalisability of findings to other neonatal units with different resource profiles, staffing structures, or patient volumes.

Conclusion.

The study portrays a neonatal workforce that is highly motivated to protect vulnerable newborns and demonstrates strong observed adherence to the WHO Five Moments, but within a system where consistent access to enabling resources is not assured. The most policy-relevant message is not that compliance is *"solved,"* but that current performance may rely on adaptation and culture more than resilient infrastructure. Strengthening reliable point-of-care opportunity; water, soap, drying, and ABHR placement while focusing improvement efforts on the lower-performing *"before"* moments is likely to yield the most sustainable gains in neonatal infection prevention.

Declarations

Abbreviations

ABHR – Alcohol-Based Hand Rub

COM-B – Capability, Opportunity, Motivation–Behaviour model

HAI – Healthcare-Associated Infection

HBM – Health Belief Model

HCW – Healthcare Worker

HHCO – Hand Hygiene Compliant Observations

HHONC – Hand Hygiene Observations Non-Compliant

IPC – Infection Prevention and Control

LMIC – Low- and Middle-Income Country

NICU – Neonatal Intensive Care Unit

THOO – Total Hand Hygiene Opportunities Observed

WHO – World Health Organization

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Health Research Ethics Committee of Alex Ekwueme Federal University Teaching Hospital, Abakaliki (AEFUTHA-HREC; NHREC/16/06/25/539). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all interview participants prior to data collection. Observational data were collected without recording personal identifiers, and all quantitative and qualitative data were anonymised prior to analysis to ensure confidentiality and data protection.

Consent for publication

Not applicable.

Availability of data and materials

All data included in this study are available upon reasonable request by contacting the corresponding author, Georgian Chiaka Ibeneme, via email: ibenemegc@dufuhs.edu.ng.

Competing Interests

The authors declare that they have no competing interests with respect to the research, authorship, and/or publication of this article.

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Authors' contributions

GCI conceived the study idea and led the overall study design. CCO; DNA; NO; CLO; and BC contributed to the development of the study methodology and data collection tools. GCI coordinated data collection, including direct observation, infrastructure assessment, and qualitative interviews. Quantitative data analysis was conducted by GCI; SCI; with input from KEF, and AIO. Qualitative analysis and interpretation were undertaken collaboratively by GCI; SCI, KEF, and AIO. All authors contributed to the interpretation of findings, critically reviewed and revised the manuscript for intellectual content, and approved the final version for publication.

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