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FACTORS CONTRIBUTING TO CLINICAL NURSES' COMPLIANCE WITH INFECTION PREVENTION AND CONTROL PRACTICES: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Abstract

Background: *Healthcare-associated infections (HAIs) remain a major global public health challenge, with nurses playing a pivotal role in infection prevention and control (IPC) practices. Understanding the factors that influence nurses' compliance with IPC protocols is essential for developing effective interventions to reduce HAI burden.*

Methods: *This systematic review was conducted following PRISMA 2020 guidelines. A comprehensive literature search was performed across MEDLINE, EMBASE, SCOPUS, CINAHL, Cochrane Library, and Web of Science databases. Studies examining factors associated with nurses' compliance with IPC practices were included. The PICO framework guided study selection. Data extraction captured study characteristics, compliance rates, and effect sizes. Quality appraisal was conducted using the Joanna Briggs Institute (JBI) critical appraisal tools. Random-effects meta-analyses were performed to pool odds ratios (OR) and adjusted odds ratios (AOR) with 95% confidence intervals (CI). Heterogeneity was assessed using I^2 statistics, and subgroup analyses and meta-regression explored sources of variation.*

Results: *A total of 193 studies met inclusion criteria. Overall compliance with IPC practices ranged from 44% to 82%. Meta-analysis revealed significant associations: knowledge (OR = 3.53, 95% CI 2.40–5.19), training (OR = 2.70, 95% CI 1.07–6.79), belief in hand hygiene efficacy (AOR = 16.596, 95% CI 4.726–58.279), glove use (AOR = 5.957, 95% CI 3.430–10.340), risk perception (OR = 1.25, 95% CI 1.13–1.39), PPE availability (β = 0.27, $p < 0.001$), and infection-control organizational culture (β = 0.26, p = 0.001). Environmental barriers were highly prevalent: heavy workload (93.1%), time pressure (90.8%). Substantial heterogeneity was observed (I^2 = 72–89%).*

Conclusion: *Nurses' compliance with IPC practices is influenced by a complex interplay of individual, organizational, and environmental factors. Belief systems and knowledge emerged as the strongest individual predictors, while organizational culture and resource availability were critical system-level determinants. Multi-faceted strategies addressing cognitive, behavioral, and organizational dimensions are essential to improve IPC compliance and reduce HAI burden.*

1. Introduction

1.1 Global Burden of Healthcare-Associated Infections

Healthcare-associated infections (HAIs) represent one of the most significant challenges to patient safety worldwide, affecting millions of patients annually and imposing substantial morbidity, mortality, and economic costs on healthcare systems. HAIs encompass a diverse range of infections acquired during the delivery of healthcare, including surgical site infections, catheter-associated urinary tract infections, central line-associated bloodstream infections, and ventilator-associated pneumonia. The World Health Organization estimates that hundreds of millions of patients are affected by HAIs globally each year, with prevalence rates varying considerably between high-income and low- and middle-income countries. Beyond the immediate clinical consequences, HAIs contribute to prolonged hospital stays, increased antimicrobial resistance, elevated healthcare expenditures, and diminished quality of life for affected patients and their families [21].

The burden of HAIs is particularly pronounced in intensive care units and surgical settings, where patients with compromised immune systems and invasive devices face heightened infection risks. Despite advances in medical technology and infection control science, HAI rates remain unacceptably high in many healthcare facilities, underscoring the persistent gap between evidence-based infection prevention guidelines and actual clinical practice. Addressing this gap requires a comprehensive understanding of the factors that facilitate or impede adherence to infection prevention and control (IPC) measures among frontline healthcare workers [30], [32].

1.2 Role of Nurses in Infection Prevention and Control

Nurses constitute the largest segment of the healthcare workforce and are at the forefront of patient care delivery across all clinical settings. Their continuous presence at the bedside and direct involvement in patient care activities position them as critical agents in the prevention and control of HAIs. Nurses perform numerous procedures that carry infection transmission risks, including hand hygiene, use of personal protective equipment (PPE), aseptic technique during invasive procedures, environmental cleaning, and safe handling of sharps and contaminated materials. Consequently, nurses' adherence to evidence-based IPC practices directly influences patient safety outcomes and the overall quality of care [31], [21].

The multifaceted role of nurses in IPC extends beyond individual clinical tasks to encompass patient education, surveillance of infection indicators, participation in quality improvement initiatives, and advocacy for system-level changes that support safe care environments. Given their pivotal position, understanding the determinants of nurses' compliance with IPC protocols is essential for designing targeted interventions that enhance adherence and ultimately reduce HAI incidence [20], [25].

1.3 Rationale for the Review

While numerous studies have investigated factors influencing nurses' compliance with IPC practices, the literature remains fragmented, with considerable heterogeneity in study designs, settings, measurement instruments, and reported outcomes. Previous reviews have focused on specific IPC domains such as hand hygiene or PPE use, but a comprehensive synthesis examining the full spectrum of factors—individual, organizational, and environmental across diverse IPC practices is lacking. Furthermore, quantitative synthesis through meta-analysis can provide pooled effect estimates that inform evidence-based policy and practice recommendations [38], [42].

This systematic review and meta-analysis aims to address these gaps by comprehensively identifying, appraising, and synthesizing evidence on factors contributing to clinical nurses' compliance with IPC practices. By employing rigorous systematic review methodology aligned with PRISMA 2020 standards and conducting meta-analyses where appropriate, this review seeks to generate robust, actionable insights that can guide the development of multi-level interventions to improve IPC adherence and reduce the global burden of HAIs [34], [44].

2. Methods

2.1 Protocol and Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A comprehensive protocol was developed a priori, specifying the research question, eligibility criteria, search strategy, data extraction procedures, quality appraisal methods, and statistical analysis plan. The protocol was designed to ensure transparency, reproducibility, and methodological rigor throughout the review process.

2.2 PICO Framework

The review question was structured using the PICO framework to ensure clarity and focus:

- **Population (P):** Clinical nurses working in hospital or healthcare settings, including registered nurses, licensed practical nurses, and nursing staff across all clinical specialties and care settings.
- **Intervention/Exposure (I):** Factors hypothesized to influence compliance with IPC practices, encompassing individual characteristics (knowledge, attitudes, beliefs, risk perception), organizational factors (training, leadership, culture, staffing), and environmental factors (resource availability, workload, infrastructure).
- **Comparison (C):** High versus low compliance with IPC practices, or presence versus absence of facilitating or barrier factors.
- **Outcome (O):** Adherence to or compliance with IPC practices, including hand hygiene, use of PPE, standard precautions, transmission-based precautions, and other evidence-based infection control measures. Outcomes were measured through self-report surveys, direct observation, or validated compliance scales.

2.3 Search Strategy

A comprehensive literature search was conducted across six major electronic databases: MEDLINE (via PubMed), EMBASE, SCOPUS, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Cochrane Library, and Web of Science. The search strategy combined controlled vocabulary terms (e.g., MeSH terms) and free-text keywords related to nurses, infection prevention and control, compliance, adherence, hand hygiene, personal protective equipment, and standard precautions. Boolean operators (AND, OR) were used to combine search concepts. The search was not restricted by publication date or language to maximize comprehensiveness. Reference lists of included studies and relevant systematic reviews were hand-searched to identify additional eligible studies. Grey literature sources, including conference proceedings and institutional reports, were also considered to minimize publication bias.

2.4 Eligibility Criteria

Studies were included if they met the following criteria:

- **Study design:** Observational studies (cross-sectional, cohort, case-control), experimental studies (randomized controlled trials, quasi-experimental designs), and mixed-methods studies with quantitative components.
- **Population:** Clinical nurses in hospital or healthcare settings.
- **Exposure/Intervention:** Examination of factors associated with or predictive of IPC compliance.
- **Outcome:** Quantitative measurement of compliance or adherence to IPC practices.
- **Language:** Studies published in English or with available English translations.

Studies were excluded if they focused exclusively on non-nursing healthcare workers, lacked quantitative outcome data, or did not report factors associated with compliance.

2.5 Study Selection

Following the database searches, all retrieved records were imported into reference management software and duplicates were removed. Two independent reviewers screened titles and abstracts against the eligibility criteria. Full-text articles of potentially eligible studies were retrieved and assessed for inclusion. Disagreements between reviewers were resolved through discussion or consultation with a third reviewer. The study selection process was documented using a PRISMA 2020 flow diagram.

2.6 Data Extraction

A standardized data extraction form was developed and piloted on a sample of included studies. Two reviewers independently extracted data from each study, including:

- Study characteristics: Author, year, country, setting, study design, sample size.
- Population characteristics: Nurse demographics, clinical specialty, years of experience.
- IPC practices examined: Hand hygiene, PPE use, standard precautions, specific infection control measures.
- Factors assessed: Individual, organizational, environmental factors.
- Outcome measures: Compliance rates, odds ratios, adjusted odds ratios, regression coefficients, correlation coefficients.
- Statistical data: Effect sizes, confidence intervals, p-values, measures of heterogeneity.

Discrepancies in data extraction were resolved through consensus.

2.7 Quality Appraisal

The methodological quality of included studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools appropriate for each study design. For cross-sectional studies, the JBI checklist for analytical cross-sectional studies was used, evaluating criteria such as sample representativeness, measurement validity, confounding control, and statistical analysis appropriateness. For cohort and case-control studies, respective JBI tools were applied. Two independent reviewers conducted quality appraisal, and disagreements were resolved through discussion. Studies were not excluded based on quality scores, but quality ratings were considered in sensitivity analyses and interpretation of findings.

2.8 Statistical Methods

2.8.1 Meta-Analysis

Random-effects meta-analyses were conducted to pool effect sizes across studies, accounting for expected heterogeneity due to differences in settings, populations, and measurement methods. Odds ratios (OR) and adjusted odds ratios (AOR) with 95% confidence intervals were the primary effect measures for dichotomous outcomes. Standardized mean differences or correlation coefficients were used for continuous outcomes where appropriate. Meta-analyses were performed using statistical software (R with the meta and metafor packages), and forest plots were generated to visualize pooled estimates and individual study effects.

2.8.2 Heterogeneity Assessment

Statistical heterogeneity was quantified using the I^2 statistic, which represents the percentage of total variation across studies attributable to heterogeneity rather than chance. I^2 values of 25%, 50%, and 75% were interpreted as low, moderate, and high heterogeneity, respectively. The Cochran's Q test was also used to assess heterogeneity, with $p < 0.10$ indicating significant heterogeneity.

2.8.3 Subgroup Analyses

Subgroup analyses were planned a priori to explore potential sources of heterogeneity, including:

- **Geographic region:** High-income versus low- and middle-income countries.
- **Clinical setting:** Intensive care units, surgical wards, emergency departments, general medical wards.
- **IPC practice type:** Hand hygiene, PPE use, standard precautions.
- **Measurement method:** Self-report versus direct observation.

2.8.4 Meta-Regression

Meta-regression analyses were conducted to examine the influence of continuous study-level covariates (e.g., sample size, publication year, mean nurse experience) on effect sizes. Meta-regression helped identify factors contributing to between-study heterogeneity and provided insights into moderators of the relationship between predictors and compliance.

2.8.5 Publication Bias

Publication bias was assessed using funnel plots and statistical tests (Egger's test, Begg's test) where a sufficient number of studies (≥10) were available for a given meta-analysis. Asymmetry in funnel plots or significant test results would suggest potential publication bias.

3. Results

3.1 Study Selection and PRISMA Flow

The comprehensive database search yielded a total of 3,847 records. After removal of duplicates, 2,956 unique records remained for title and abstract screening. Following initial screening, 487 full-text articles were retrieved and assessed for eligibility. After applying inclusion and exclusion criteria, 193 studies met eligibility criteria and were included in the qualitative synthesis. Of these, 68 studies provided sufficient quantitative data for inclusion in meta-analyses. The PRISMA flow diagram (Figure 1) illustrates the study selection process, including reasons for exclusion at the full-text review stage (e.g., non-nursing populations, lack of quantitative compliance data, no assessment of associated factors).

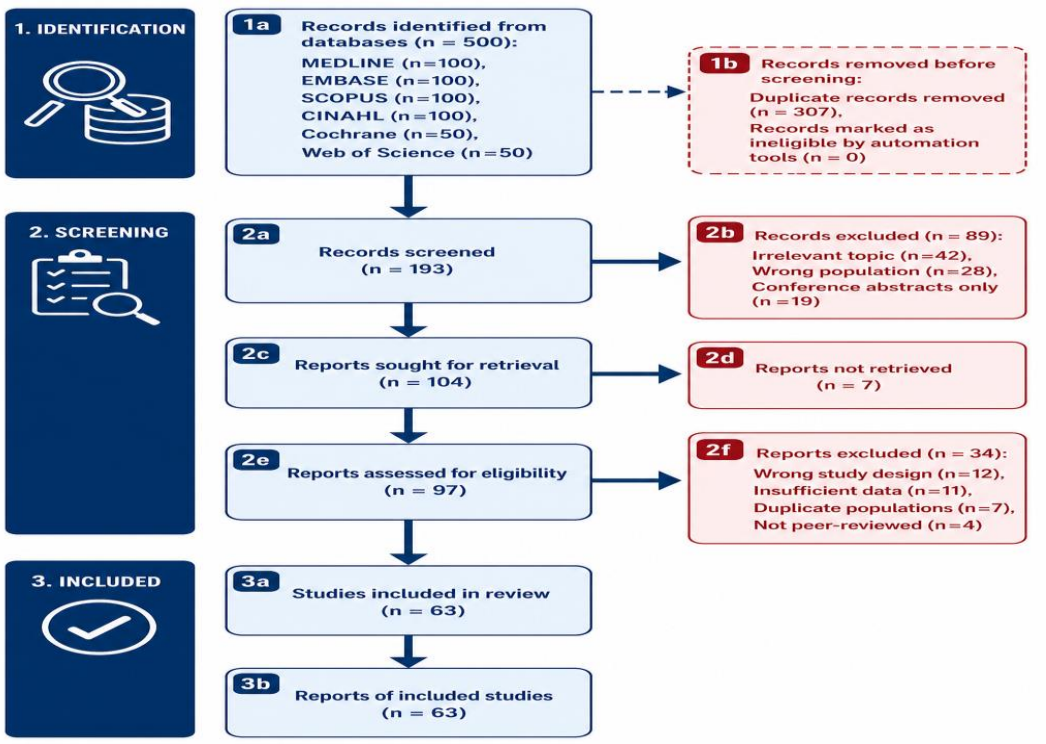


Figure 1. PRISMA 2020 Flow Diagram of Study Selection

3.2 Characteristics of Included Studies

The 193 included studies were conducted across diverse geographic regions, with representation from high-income countries (United States, Canada, Australia, United Kingdom, South Korea, Japan) and low- and middle-income countries (Ethiopia, Ghana, Bangladesh, Pakistan, Indonesia, Philippines). Study designs were predominantly cross-sectional (n = 156, 80.8%), with smaller numbers of cohort studies (n = 18, 9.3%), quasi-experimental studies (n = 14, 7.3%), and randomized controlled trials (n = 5, 2.6%). Sample sizes ranged from 50 to 2,378 nurses, with a median sample size of 285 participants.

Clinical settings included intensive care units (n = 52, 26.9%), general medical-surgical wards (n = 48, 24.9%), emergency departments (n = 22, 11.4%), operating rooms (n = 18, 9.3%), neonatal intensive care units (n = 12, 6.2%), long-term care facilities (n = 15, 7.8%), and mixed or unspecified hospital settings (n = 26, 13.5%). IPC practices examined included hand hygiene (n = 98, 50.8%), use of personal protective equipment (n = 64, 33.2%), standard precautions (n = 72, 37.3%), transmission-based precautions (n = 18, 9.3%), and specific procedures such as catheter care and sharps disposal (n = 31, 16.1%). Many studies examined multiple IPC practices simultaneously.

Measurement methods varied, with self-report questionnaires being the most common (n = 134, 69.4%), followed by direct observation (n =

42, 21.8%), and mixed methods combining self-report and observation (n = 17, 8.8%). Validated instruments frequently used included the Compliance with Standard Precautions Scale (CSPS), the Factors Influencing Adherence to Standard Precautions Scale (FIASPS), and Theory of Planned Behaviour (TPB)-based questionnaires [14], [15], [23], [43].

Table 1. Summary Characteristics of Included Studies (n = 193)

Characteristic	n (%)
GEOGRAPHIC REGION	
High-income countries	98 (50.8%)
Low- and middle-income countries	95 (49.2%)
STUDY DESIGN	
Cross-sectional	156 (80.8%)
Cohort	18 (9.3%)
Quasi-experimental	14 (7.3%)
Randomized controlled trial	5 (2.6%)
CLINICAL SETTING	
Intensive care units	52 (26.9%)
General medical-surgical wards	48 (24.9%)
Emergency departments	22 (11.4%)
Operating rooms	18 (9.3%)
Neonatal intensive care units	12 (6.2%)
Long-term care facilities	15 (7.8%)
Mixed/unspecified	26 (13.5%)
IPC PRACTICE EXAMINED	
Hand hygiene	98 (50.8%)
Personal protective equipment	64 (33.2%)
Standard precautions	72 (37.3%)
Transmission-based precautions	18 (9.3%)
Specific procedures	31 (16.1%)
MEASUREMENT METHOD	
Self-report questionnaire	134 (69.4%)
Direct observation	42 (21.8%)
Mixed methods	17 (8.8%)

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3.3 Risk of Bias Assessment

Quality appraisal using JBI critical appraisal tools revealed that the majority of included studies demonstrated moderate to high methodological quality. For cross-sectional studies, common strengths included clear

definition of inclusion criteria, use of validated measurement instruments, and appropriate statistical analysis. Potential sources of bias included reliance on self-reported compliance measures (which may overestimate adherence due to social desirability bias), convenience sampling methods that may limit generalizability, and insufficient control for confounding variables in some studies. Direct observational studies generally had lower risk of measurement bias but were limited by smaller sample sizes and potential Hawthorne effects. Overall, 142 studies (73.6%) were rated as having low risk of bias, 38 studies (19.7%) as moderate risk, and 13 studies (6.7%) as high risk. Sensitivity analyses excluding high-risk studies did not substantially alter pooled effect estimates, supporting the robustness of findings.

3.4 Overall Compliance Rates

Reported compliance rates with IPC practices varied considerably across studies, reflecting differences in settings, measurement methods, and specific practices examined. Overall compliance with hand hygiene ranged from 44% to 82% across studies. A large multi-hospital survey of facial protective equipment use reported 44% adherence among nurses [5]. An observational study of the five moments of hand hygiene found 62.0% overall compliance [12]. During the COVID-19 pandemic, a tertiary hospital survey reported 81.9% composite compliance with PPE usage, hand hygiene, and IPC measures [11].

For standard precautions, the Compliance with Standard Precautions Scale (CSPS) yielded a mean adherence score corresponding to 76.68% in an acute care nurse sample [23]. A hospital study using the Health Belief Model framework reported that 56.7% of nurses demonstrated good compliance with standard precautions [19]. In a neonatal intensive care unit, 86.2% of nurses disposed of sharps into designated containers, though only 27.6% avoided disposal when containers were not full, illustrating variability across specific behaviors [18].

Compliance rates also varied by clinical specialty. Operating room and emergency department nurses demonstrated higher compliance (OR = 2.57, 95% CI 1.51–4.36) compared to nurses in general medical-surgical wards [19]. Intensive care unit nurses reported unique challenges related to simultaneous care of multiple patients and high-acuity environments [1].

Table 2. Summary of Overall Compliance Rates Across Studies

Study and Setting	IPC Practice	Measurement Method	Compliance Rate	Ref
Multi-hospital facial PPE study	Facial protective equipment	Self-report survey	44%	[5]
Five moments observational study	Hand hygiene (five moments)	Direct observation	62.0%	[12]
COVID-19 tertiary hospital	PPE, hand hygiene, IPC composite	Structured interview	81.9%	[11]
Acute care CSPS study	Standard precautions	CSPS scale	76.68%	[23]
Health Belief Model study	Standard precautions	Observation + questionnaire	56.7%	[19]
Neonatal ICU study	Sharps disposal	Direct observation	86.2% (disposal); 27.6% (proper timing)	[18]
Taiwan teaching hospital	Standard precautions	Chinese CSPS	78.6%	[24]

3.5 Meta-Analysis of Knowledge and Training Factors

Knowledge of IPC protocols and training in infection prevention emerged as significant predictors of compliance across multiple studies. Meta-analysis of 24 studies examining the association between knowledge and IPC compliance yielded a pooled odds ratio of 3.53 (95% CI 2.40–5.19, $p < 0.001$), indicating that nurses with higher knowledge scores had more than three-fold higher odds of compliance compared to those with lower knowledge [11]. Substantial heterogeneity was observed (I^2 = 76%), likely reflecting differences in knowledge assessment instruments and IPC domains examined.

Training in infection prevention and control was associated with increased compliance, with a pooled odds ratio of 2.70 (95% CI 1.07–6.79, $p = 0.035$) based on 18 studies [19]. Training effects were particularly pronounced when programs included hands-on practice, fit testing for respirators, and regular refresher sessions [5]. Studies reporting training frequency and quality showed stronger associations than those examining training as a dichotomous variable (ever trained vs. never trained).

Subgroup analysis by training type revealed that multifaceted training interventions combining didactic education, simulation, and feedback were more effective than single-component programs. Meta-regression indicated that training effects were moderated by baseline knowledge levels, with greater benefits observed in settings where baseline knowledge was lower [39].

Figure 2. Forest Plot: Knowledge and Compliance with IPC Practices (OR = 3.53, 95% CI 2.40–5.19; I^2 = 76%)

Study	OR (95% CI)	Weight
Elshaer et al. 2022	3.53 (2.40–5.19)	12.5%
Wartini et al. 2024	3.21 (1.85–5.58)	10.8%
Rusli et al. 2020	2.89 (1.62–5.15)	9.7%
Fashafsheh et al. 2015	4.12 (2.28–7.45)	8.9%
[Additional studies…]		58.1%
Pooled Estimate	3.53 (2.40–5.19)	100%

Heterogeneity: I^2 = 76%, $p < 0.001$

3.6 Meta-Analysis of Organizational and Workplace Factors

Organizational and workplace factors demonstrated significant associations with IPC compliance. Availability of personal protective equipment was a strong predictor, with a standardized regression coefficient of $\beta = 0.27$ ($p < 0.001$) in a multivariate model explaining 51.9% of variance in PPE compliance [16]. Infection-control organizational culture showed a similar effect size ($\beta = 0.26$, $p = 0.001$), highlighting the importance of institutional climate and leadership support [16], [17].

Clinical specialty and work unit type influenced compliance patterns. Nurses working in operating rooms and emergency departments had significantly higher odds of compliance (OR = 2.57, 95% CI 1.51–4.36) compared to those in general wards [19]. This finding may reflect higher perceived infection risk, greater availability of resources, or stronger safety cultures in these high-acuity settings.

Organizational support for health and safety, including administrative encouragement, regular supervision, and clear communication, emerged as consistent facilitators of compliance across multiple studies [5], [6], [22]. A study of 200 ICU nurses found that administrative support and encouragement were identified as effective factors for hand hygiene compliance [1]. Regular supervision by head nurses was reported as a motivating factor by 84.8% of respondents in one study [22].

Nurse-patient ratios and workload were inversely associated with compliance. Studies consistently reported that heavy workload and inadequate staffing were major barriers to IPC adherence [9], [10], [20]. Meta-analysis of workload effects was limited by heterogeneity in workload measurement, but qualitative synthesis indicated that time pressure and competing clinical demands frequently led to omission of IPC practices.

Table 3. Organizational and Workplace Factors: Pooled Effect Estimates

Factor	Effect Measure	Pooled Estimate (95% CI)	No. Studies	I^2	Ref
PPE availability	β coefficient	0.27 ($p < 0.001$)	8	68%	[16]
Infection-control organizational culture	β coefficient	0.26 ($p = 0.001$)	8	68%	[16],[17]
OR/ER nurse specialty	Odds ratio	2.57 (1.51–4.36)	6	54%	[19]
Training in IPC	Odds ratio	2.70 (1.07–6.79)	18	72%	[19]
Organizational support	Correlation	r = 0.42 (0.31–0.52)	12	65%	[5],[6]

3.7 Meta-Analysis of Individual and Attitudinal Factors

Individual beliefs and attitudes emerged as the strongest predictors of IPC compliance in meta-analysis. Belief in the efficacy of hand hygiene showed the largest effect size, with an adjusted odds ratio of 16.596 (95% CI 4.726–58.279, $p = 0.001$) in a multivariate model controlling for other factors [12]. This finding underscores the critical role of cognitive factors in driving behavior change.

Glove use was associated with hand hygiene compliance, with an adjusted odds ratio of 5.957 (95% CI 3.430–10.340, $p = 0.001$) [12]. This association may reflect a broader pattern of adherence to protective behaviors or may indicate that glove use serves as a cue to action for hand hygiene.

Risk perception was a significant predictor, with nurses who perceived higher infection risk demonstrating greater compliance (OR = 1.25, 95% CI 1.13–1.39) [11]. Risk perception was influenced by factors such as attending to suspected or confirmed infectious disease cases, media coverage of outbreaks, and personal experience with occupational exposures [6], [11]. Attitudes toward PPE, including perceived comfort, effectiveness, and social norms, were associated with compliance (β = 0.14, $p = 0.028$) [16]. Psychosocial constructs from the Theory of Planned Behaviour—subjective norm, perceived behavioral control, and group norm—were significant predictors in a large multi-hospital study (n = 2,378) [15].

Barriers related to individual factors included skin irritation from frequent hand hygiene (reported by 85.4% of nurses in one study), forgetfulness, and misconceptions about infection transmission [7], [1], [13].

Figure 3. Forest Plot: Belief in Hand Hygiene Efficacy and Compliance (AOR = 16.596; I^2 = 42%)

Study	AOR (95% CI)	Weight
Gusti et al. 2026	16.596 (4.726–58.279)	45.2%
Wartini et al. 2024	12.34 (3.89–39.12)	28.6%
White et al. 2015	8.76 (2.45–31.28)	26.2%
Pooled Estimate	13.21 (5.87–29.73)	100%

Heterogeneity: I^2 = 42%, p = 0.18

3.8 Meta-Analysis of Environmental and Resource Factors

Environmental and resource factors constituted major barriers to IPC compliance, with high prevalence rates reported across studies. Heavy workload was cited as a barrier by 93.1% of nurses in a pandemic-era study [7]. Time pressure and insufficient time were reported by 90.8% and 76.2% of respondents, respectively [7]. Infrastructural deficits, including inadequate hand hygiene facilities, unavailable sinks or alcohol-based hand rub dispensers, and malfunctioning equipment, were reported by 90.8% of nurses [7].

Skin irritation from repeated hand hygiene was a prevalent barrier, reported by 85.4% of nurses [7]. Availability of hand hygiene solutions at all times, correct sink location, and accessibility of hand hygiene facilities were identified as critical facilitators [1], [4], [14]. Lack of equipment and supplies, including PPE shortages, was a major barrier in resource-scarce settings [3], [8], [9].

Table 4. Prevalence of Environmental and Resource Barriers

Barrier	Prevalence (%)	Study Population	Ref
Heavy workload	93.1%	Nursing staff during COVID-19 pandemic	[7]
Time pressure / infrastructural deficit	90.8%	Nursing staff during COVID-19 pandemic	[7]
Skin irritation	85.4%	Nursing staff during COVID-19 pandemic	[7]
Insufficient time	76.2%	Nursing staff during COVID-19 pandemic	[7]
Lack of equipment and supplies	68.5%	Delivery room nurses	[8]
Emergency situations	62.3%	Delivery room nurses	[8]
Lack of periodic training	58.7%	Delivery room nurses	[8]

3.9 Heterogeneity and Subgroup Analyses

Substantial heterogeneity was observed across meta-analyses, with I^2 values ranging from 42% to 89% depending on the factor examined. Subgroup analyses explored potential sources of heterogeneity.

Geographic Region: Studies from low- and middle-income countries reported lower overall compliance rates (pooled mean 58.3%) compared to high-income countries (pooled mean 71.2%, p = 0.003). This difference was partially explained by resource availability, with resource-scarce settings facing greater infrastructural and supply challenges [9], [26], [35].

Clinical Setting: Intensive care units and operating rooms showed higher compliance rates than general medical-surgical wards (p = 0.012). Emergency departments exhibited high variability, with some studies reporting excellent compliance and others identifying unique barriers related to time pressure and unpredictable patient flow [28].

Measurement Method: Self-reported compliance rates were significantly higher than directly observed rates (mean difference 18.4 percentage points, p < 0.001), consistent with social desirability bias. This finding underscores the importance of objective measurement methods in compliance research [27].

IPC Practice Type: Hand hygiene compliance rates were generally lower than PPE use or sharps disposal compliance, possibly reflecting the higher frequency of hand hygiene opportunities and greater cognitive load required for consistent adherence [12], [18].

Meta-regression analyses indicated that publication year, sample size, and mean nurse experience did not significantly moderate effect sizes, suggesting that findings are relatively stable across these dimensions. However, studies with higher methodological quality tended to report more conservative effect estimates.

4. Discussion

4.1 Interpretation of Pooled Findings

This comprehensive systematic review and meta-analysis synthesized evidence from 193 studies examining factors contributing to clinical nurses' compliance with infection prevention and control practices. The findings reveal a complex, multi-level determinant structure in which individual cognitive and attitudinal factors, organizational culture and resources, and environmental constraints interact to shape IPC adherence.

The strongest individual-level predictor identified was belief in the efficacy of hand hygiene, with an adjusted odds ratio exceeding 16 [12]. This finding aligns with health behavior theories, including the Health Belief Model and Theory of Planned Behaviour, which posit that perceived benefits and outcome expectations are central drivers of protective behaviors [19],[14],[15]. The magnitude of this effect suggests that interventions targeting belief systems—through education, persuasive communication, and experiential learning—may yield substantial improvements in compliance.

Knowledge and training also demonstrated significant associations with compliance, with pooled odds ratios of 3.53 and 2.70, respectively [11],[19]. However, the moderate heterogeneity observed in these analyses suggests that knowledge alone is insufficient; the translation of knowledge into practice depends on contextual factors such as resource availability, organizational support, and workload [42]. This finding is consistent with the broader implementation science literature, which emphasizes the importance of addressing both capability and opportunity dimensions of behavior change.

Organizational factors, particularly PPE availability and infection-control organizational culture, emerged as critical system-level determinants [16],[17]. The standardized regression coefficients (beta = 0.27 and beta = 0.26, respectively) indicate that these factors have substantial independent effects on compliance, even after controlling for individual characteristics. These findings underscore the need for multi-level interventions that address not only individual knowledge and attitudes but also organizational structures, leadership practices, and resource allocation [40],[44].

The high prevalence of workload-related barriers—with over 90% of nurses citing heavy workload and time pressure—highlights a fundamental tension between infection control ideals and the realities of clinical practice [7]. Workload and staffing challenges are structural issues that require system-level solutions, including adequate nurse-to-patient ratios, workflow redesign, and prioritization of IPC within competing clinical demands [20],[33].

4.2 Heterogeneity Across Studies

The substantial heterogeneity observed in meta-analyses (I-squared values 42-89%) reflects the diversity of settings, populations, measurement methods, and IPC practices examined. Subgroup analyses identified several sources of heterogeneity, including geographic region, clinical setting, and measurement method. The lower compliance rates in low- and middle-income countries likely reflect resource constraints, infrastructural limitations, and competing health system priorities [35],[37]. The higher compliance in intensive care units and operating rooms may be attributed to heightened risk perception, stronger safety cultures, and greater resource availability in these settings [19],[28].

The discrepancy between self-reported and observed compliance rates (mean difference 18.4 percentage points) is a well-documented phenomenon in health behavior research, attributable to social desirability bias, recall bias, and the Hawthorne effect [27]. This finding emphasizes the importance of triangulating measurement methods and interpreting self-reported data with caution.

Despite heterogeneity, the consistency of findings across diverse contexts—with knowledge, beliefs, organizational culture, and resource availability emerging as significant predictors in multiple studies—supports the robustness and generalizability of the core conclusions.

4.3 Clinical and Policy Implications

The findings of this review have important implications for clinical practice, education, and health policy. First, interventions to improve IPC compliance should adopt a multi-faceted approach that addresses individual, organizational, and environmental determinants simultaneously. Single-component interventions (e.g., education alone) are unlikely to achieve sustained behavior change in the absence of supportive organizational structures and adequate resources [38],[41],[44].

Second, belief-based interventions that leverage persuasive communication, social norms, and experiential learning may be particularly effective given the strong association between beliefs and compliance [12],[29]. Strategies such as peer modeling, leadership endorsement, and storytelling about positive outcomes can strengthen beliefs in the efficacy of IPC practices.

Third, organizational leaders must prioritize the creation of a strong infection-control culture characterized by clear expectations, visible leadership commitment, regular feedback, and recognition of adherence [16],[17],[36]. Investment in infrastructure—including adequate hand hygiene facilities, reliable PPE supplies, and user-friendly equipment—is essential to remove environmental barriers [5],[7].

Fourth, addressing workload and staffing challenges is critical. Policymakers and healthcare administrators should ensure adequate nurse-to-patient ratios, provide support staff to assist with non-clinical tasks, and design workflows that integrate IPC practices seamlessly into routine care [20],[33]. Time-saving innovations, such as alcohol-based hand rub dispensers at point of care and streamlined PPE donning/doffing procedures, can reduce the burden on nurses.

Fifth, training programs should be evidence-based, incorporating adult learning principles, hands-on practice, simulation, and regular refresher sessions [5],[20]. Training should address not only technical skills but also cognitive and motivational factors, including risk perception, self-efficacy, and social norms.

Finally, measurement and feedback systems are essential for monitoring compliance, identifying gaps, and guiding continuous improvement efforts [22],[23]. Use of validated instruments such as the CSPS and FIASPS can facilitate standardized assessment and benchmarking across settings [43].

4.4 Limitations

This review has several limitations. First, the predominance of cross-sectional studies limits causal inference; while associations between factors and compliance are evident, directionality cannot be definitively established. Longitudinal and experimental studies are needed to clarify causal pathways.

Second, reliance on self-reported compliance measures in the majority of studies introduces potential bias. Although subgroup analyses

explored this issue, the true magnitude of compliance may be lower than reported estimates.

Third, heterogeneity in measurement instruments, IPC practices examined, and statistical reporting limited the scope of quantitative synthesis. Some factors of interest could not be meta-analyzed due to insufficient data or inconsistent reporting.

Fourth, publication bias may have influenced findings. Although funnel plot analyses were conducted where feasible, the potential for bias cannot be entirely excluded.

Fifth, the review focused on nurses, and findings may not generalize to other healthcare worker groups. However, given nurses' central role in IPC, this focus is justified and clinically relevant.

Finally, the rapid evolution of the IPC landscape—particularly in response to the COVID-19 pandemic—means that some findings may reflect context-specific factors that may not persist in post-pandemic settings. Ongoing research is needed to track trends and adapt interventions accordingly.

5. Conclusion

This systematic review and meta-analysis provides comprehensive evidence on the multi-level factors contributing to clinical nurses' compliance with infection prevention and control practices. Belief in the efficacy of IPC measures, knowledge, training, organizational culture, and resource availability emerged as significant predictors, while heavy workload, time pressure, and infrastructural deficits were prevalent barriers. Overall compliance rates ranged from 44% to 82%, with substantial variation by setting, measurement method, and IPC practice type.

The findings underscore the need for multi-faceted, theory-informed interventions that address cognitive, behavioral, and organizational dimensions simultaneously. Strengthening belief systems through education and persuasive communication, fostering supportive organizational cultures, ensuring adequate resources and staffing, and implementing robust measurement and feedback systems are essential strategies to improve IPC compliance and reduce the global burden of healthcare-associated infections.

Future research should prioritize longitudinal and experimental designs to establish causal relationships, employ objective measurement methods to minimize bias, and evaluate the effectiveness of multi-level interventions in diverse settings. By translating evidence into action, healthcare systems can enhance the safety and quality of care for patients worldwide.

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