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A pilot study on the impact of blended learning in enhancing nurses' hand hygiene knowledge

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ABSTRACT

This pilot study aims to assess changes in nurses' knowledge of hand hygiene before and after the implementation of a blended learning method – combining an eight-hour practical simulation with an e-learning module – based on the World Health Organization's (WHO) 'My 5 Moments for Hand Hygiene' framework, and to provide further scientific insight into the applicability of this educational approach. The study focuses on three key research questions: 1) how e-learning and practical simulations influence nurses' awareness of hand hygiene principles based on the WHO 'My 5 Moments for Hand Hygiene' framework, 2) whether there are statistically significant differences in nurses' knowledge before and after the blended learning intervention by the WHO framework, and 3) how suitable the assessment tool used in this study is for planning more extensive research in the future. The participants are the nurses who attended the training. Data were collected using the WHO hand hygiene knowledge questionnaire from March to May 2023, and responses from 50 (91%) participants were analysed. Although this is a small-scale study, the results show significant improvement in awareness regarding hand hygiene methods after exposure to blood (52% vs 80%, $\chi^2 = 8.369$, $p = 0.004$), the need for hand cream (74% vs 90%, $\chi^2 = 6.342$, $p = 0.042$), and the use of hand disinfection and washing techniques (78% vs 92%, $\chi^2 = 3.843$, $p = 0.050$). However, no improvement was seen in nurses' understanding of hand hygiene after emptying a bedpan. Additionally, there was insufficient awareness that the contaminated hands of healthcare workers are a significant source of germs in healthcare settings. The study found no links between nurses' knowledge and their gender, age, or department. The assessment tool used in this study is suitable for conducting a more extensive analysis.

1. Introduction

Patient and staff safety is a priority for any healthcare system. Hand hygiene is one of the most critical measures in healthcare facilities for preventing the spread of hospital-acquired infections and protecting patients and healthcare workers (Martos-Cabrera et al. 2019). Research has shown that appropriate hand hygiene reduces the risk of infection and creates a safer and more reliable environment. The role of nurses in this context is critical as their direct contact with patients makes them primary responders in preventing the spread of microorganisms (Basurrah and Madani 2006; Vaishnav et al. 2016; Graveto et al. 2018). The World Health Organization (WHO) framework 'My 5 Moments for Hand Hygiene' provides a structured and evidence-based approach to implementing hand hygiene in nurses' daily work, aiming to optimize the interruption of microbial transmission (McKay and Shaban 2023). The framework emphasizes the importance of hand hygiene at five key moments: before patient contact, before aseptic procedures, after exposure to body fluids, after patient care, and after contact with the patient's immediate environment (WHO 2009; Boyce 2019).

Martos-Cabrera et al. (2019) and Fernandes et al. (2024) highlight that the effectiveness of hand hygiene depends on nurses' ability to adhere to timing requirements accurately. This awareness is closely linked to the quality of training programmes (Baggett et al. 2014; Shinde and Mohite 2014; Nakamura et al. 2019;

Sagar et al. 2020; Sofiana et al. 2020; Lotfinejad et al. 2021; Ahmadipour et al. 2022; Fernandes et al. 2024). Hand hygiene is a practical skill that requires systematic practice and evidence-based training (Kim and Jeong 2021). Theoretical education alone does not ensure skill application in clinical practice, making a diverse approach more effective (McCutcheon et al. 2015; Martos-Cabrera et al. 2019). Blended learning combines online and practical training, offering a more flexible and effective training method (Kang and Seomun 2017; Balogun et al. 2023). The use of blended learning in the education of nursing students in healthcare higher education institutions has been extensively studied, demonstrating its potential to enhance knowledge acquisition and retention (Li et al. 2019; Du et al. 2022). However, its impact on the hand hygiene knowledge of nurses in clinical settings has received limited attention, and existing studies are methodologically constrained and heterogeneous (McCutcheon et al. 2015; Martos-Cabrera et al. 2019). This pilot study aims to assess changes in nurses' knowledge of hand hygiene before and after the implementation of a blended learning method – combining an eight-hour practical simulation with an e-learning module – based on the WHO 'My 5 Moments for Hand Hygiene' framework, and to provide further scientific insight into the applicability of this educational approach. The study focuses on three key research questions: 1) how e-learning and practical simulations influence nurses' awareness of hand hygiene principles based on the WHO 'My 5 Moments for Hand Hygiene' framework, 2) whether there are statistically significant differences in nurses' knowledge before and after the blended learning intervention by the WHO framework, and 3) how suitable the assessment tool used in this study is for planning more extensive research in the future.

2. Theoretical background

2.1. Nurses' knowledge of hand hygiene based on the WHO 'My 5 Moments for Hand Hygiene' framework

The WHO 'My 5 Moments for Hand Hygiene' framework (Fig. 1) is an internationally recognized standard aimed at reducing the spread of healthcare-associated infections and ensuring a systematic approach to hand hygiene (Boyce and Pittet 2002; WHO 2009; White et al. 2015). The framework distinguishes between 'before' (moments M1 and M2) and 'after' (moments M3, M4, and M5) indications: the former protects the patient from microorganisms transmitted by healthcare workers, while the latter prevents the spread of microorganisms from the patient or the environment to the healthcare worker (Laskar et al. 2018).

Empirical studies have shown that nurses' knowledge of the five moments of hand hygiene, as defined by the WHO, is inconsistent (Laskar et al. 2018). The observed knowledge patterns across studies indicate systemic shortcomings and the need for more targeted, context-specific interventions (White et al. 2015; Seo et al. 2019). The most significant knowledge gaps have been identified before patient contact (M1) and before aseptic procedures (M2), whereas awareness is considerably higher after exposure to body fluids (M3). This suggests a tendency to perceive biological risk as more important from a self-protection perspective than as a preventive measure to ensure patient safety (Laskar et al. 2018; Larosa et al. 2022; Svenšek et al. 2024).

Similar trends have been identified in other studies, where compliance rates are the highest after contact with body fluids (80–89.7%) and after touching the patient (62.1–69%) but the lowest before patient contact (52–59.8%) and before an aseptic procedure (37–50%) (Shobowale et al. 2016; Graveto et al. 2018; Soesanto 2018; Kim and Jeong 2021). These findings indicate that knowledge of the WHO-defined five moments of hand hygiene is most potent in situations related to self-protection, whereas moments focused on patient safety are followed less consistently (Cambil-Martin et al. 2020; Grau et al. 2024). This suggests that nurses' actual behaviour is influenced not only by their level of knowledge but also by their perception of biological risks and behavioural habits (White et al. 2015; Kim and Jeong 2021).

Empirical studies have yielded conflicting results regarding compliance with different WHO 'My 5 Moments for Hand Hygiene' categories. Shinde and Mohite (2014) found that nurses had a high level of knowledge before patient contact (M1) (91%). However, several studies have reported that the lowest compliance rates are observed not before patient contact (M1) but after touching the patient's immediate surroundings (M5), with compliance rates reported at 25.2% (Kim and Jeong 2021), 26% (Shinde and Mohite 2014), 44% (Graveto et al. 2018), 51.4% (Mestan 2019), and 78% (Soesanto 2018). These findings suggest that adherence to M5 may pose a greater challenge than previously assumed. Significant variations exist in compliance with the five moments depending on the context and the training methods applied (Laskar et al. 2018). Additionally, the study by Soesanto (2018) revealed that only 16.7% of nurses fully comply with hand hygiene guidelines, 24.4% adhere inadequately, and 59% follow inappropriate practices.

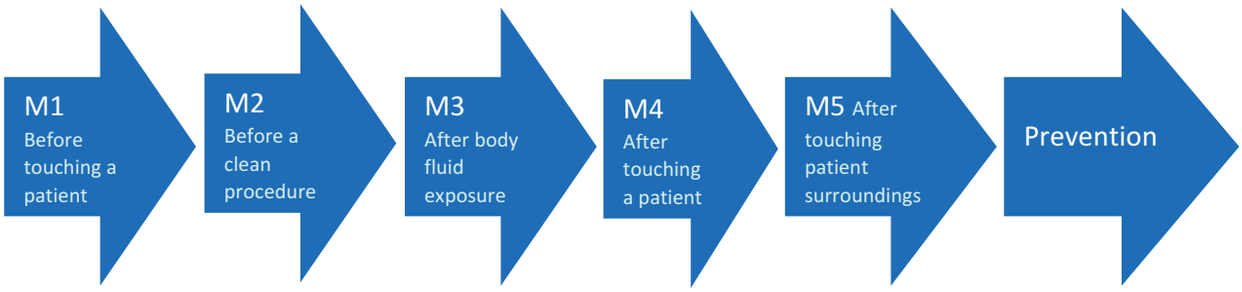

Fig. 1. The WHO 'My 5 Moments for Hand Hygiene' framework (based on WHO 2009).

Hand hygiene compliance is influenced not only by the knowledge level but also by sociodemographic factors. Research indicates that nurses with less clinical experience adhere to hygiene requirements more consistently than their more experienced colleagues (Nguyen et al. 2020; Grau et al. 2024). However, attending a single hand hygiene training session in the past year does not necessarily result in improved knowledge or more consistent hygiene practices, which emphasizes the need for continuous, practical, and interactive training. Conversely, nurses participating in multiple training sessions demonstrate better knowledge retention and compliance (Nguyen et al. 2020).

2.2. The impact of blended learning on nurses' knowledge of hand hygiene

The WHO emphasizes that improving healthcare workers' adherence to hand hygiene requires implementing diverse teaching strategies (WHO and WHO Patient Safety 2009). Blended learning is an evidence-based pedagogical approach that integrates online and in-person instruction (Graham 2006; Hrastinski 2019). Unlike traditional teaching methods, it is a strategically structured system that creates synergy between digital and practical learning, enabling flexible and contextual knowledge acquisition (Siemens et al. 2015). Empirical studies confirm that interactive methods such as video lectures, hands-on exercises, feedback, and online guidance enhance learner autonomy and improve knowledge retention and transfer to clinical practice (Xiong et al. 2017; Martos-Cabrera et al. 2019; Mestan 2019; Nakamura et al. 2019; Fouad and Eltaher 2020; Halasa et al. 2020; Ashraf et al. 2021). However, the implementation of blended learning is limited by technical barriers, resource intensity, and the need for instructor training to ensure its effectiveness and practical applicability (Rasheed et al. 2020; Vallée et al. 2020; Ashraf et al. 2021; Yu 2023). Additionally, the absence of a standardized framework for its use in healthcare education has led to inconsistencies in how it is defined and how effective it is, depending on contextual and institutional factors (Sadeghi et al. 2014).

Empirical studies have shown that blended learning is an effective method for improving nurses' knowledge of and adherence to the WHO-defined five moments of hand hygiene, yielding better results than either traditional in-person training or e-learning alone (Martos-Cabrera et al. 2019; Nakamura et al. 2019; Fouad and Eltaher 2020; Halasa et al. 2020). Liu et al. (2016) emphasize that the impact of blended learning is maximized when training includes practical simulations and e-learning components that support the clinical implementation of the WHO's five moments of hand hygiene. However, Kim and Jeong (2021) found that while blended learning improves knowledge levels immediately after training, retention is inconsistent over six months. The most significant decline was observed before patient contact (M1) and before aseptic procedures (M2), highlighting the need for repeated practical interventions and follow-up training to ensure long-term knowledge retention and application in real work environments.

Furthermore, the effectiveness of blended learning is influenced by sociodemographic factors. Grau et al. (2024) found that nurses with less work experience adhered more consistently to hand hygiene requirements after training than their more experienced colleagues, indicating the need to target additional training efforts towards experienced healthcare professionals.

3. Research methodology

3.1. Design

In this study, a descriptive cross-sectional design was implemented to assess and compare nurses' knowledge of hand hygiene before and after the application of blended learning based on the WHO-defined 'My 5 Moments for Hand Hygiene' framework. The study involved nurses from a regional hospital who participated in a structured training programme incorporating blended learning, which integrated e-learning and practical simulations.

The first part of the training programme consisted of an interactive and self-reflective e-learning module designed to incorporate textual materials, visual illustrations, videos, and self-assessment questions with explanatory answers. According to the WHO '5 Moments', the aim was to provide immediate feedback to learners and enhance their awareness of hand hygiene's technical aspects and timing. This structured, diverse learning environment fosters active learner engagement and supports deeper knowledge retention (Shieh and Hsieh 2021; Koo et al. 2023). The second part of the training programme involved an eight-hour practical simulation conducted in a dedicated simulation centre (see Fig. 2). The simulations aimed to strengthen participants' ability to identify and implement the correct moments for hand hygiene in a clinical context, following WHO guidelines. The training focused on peripheral cannula insertion, indwelling catheter insertion, and patient information sharing – critical components of nursing practice and patient safety.

To conduct the simulations, experienced instructors were involved, and a 'shame and blame' approach was avoided to minimize the participants' negative reactions (Rudolph et al. 2006). This approach emphasizes discussing mistakes in a

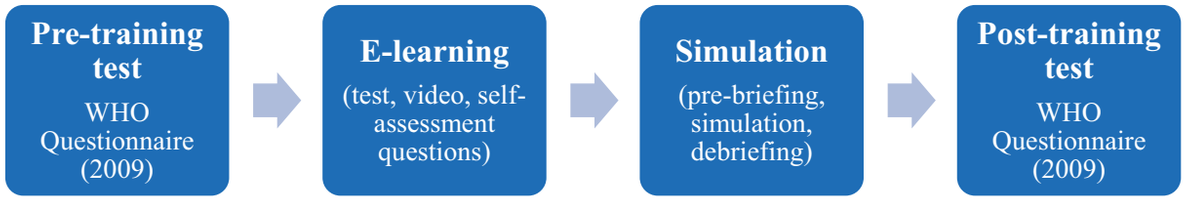

Fig. 2. The stages of this study.

way that supports learning without eliciting feelings of shame or blame rather than offering criticism and judgment. Instructors steer away from questions such as 'Can anyone tell me what went wrong here?' and instead pose questions and discussions that encourage learners to understand the situation and learn from it without feeling judged. The simulations were conducted in pairs, with a particular emphasis on debriefing – a process essential for reflection and knowledge consolidation (Gordon 2017; Koo et al. 2023). Debriefing enables participants to analyse their experiences deeply, leading to improvements in both theoretical knowledge and practical skills (Bae et al. 2019; Koo et al. 2023).

3.2. Participants

In this study, nurses (N = 55) from a single hospital participated in the training programme at Tallinn Health Care College (now Tallinn Health University of Applied Sciences). The criteria for participant selection included the nurses' educational background and their consent to participate in the study. Exclusion criteria encompassed incomplete questionnaires and non-compliance with the requirements. Three groups of nurses, each consisting of 15–20 nurses, participated in the training programme. The smaller group format allowed the participants to practice nursing activities more extensively while adhering to the WHO hand hygiene standards (Patient Safety and WHO 2009). This approach fostered individual attention and active engagement among the participants, enabling them to acquire the necessary skills for effective hand hygiene implementation (Koo et al. 2023).

3.3. Data collection

Data were collected using the WHO 2009 'Hand Hygiene Knowledge Questionnaire for Health Care Workers', which was translated into Estonian and adapted to the local context. A two-way translation was conducted to ensure the reliability of the questionnaire (Kalfoss 2019). The first part of the questionnaire focuses on the demographic information of the nurses, such as age, gender, and department. The following two questions assess whether the participant has completed training in the last three years and whether the nurses routinely use alcohol-based antiseptics. The following eight questions evaluate participants' knowledge of hand hygiene. Knowledge was assessed before and after implementing blended learning using 21 questions (response options: true/false or yes/no). A correct answer was awarded 1 point, while an incorrect answer received 0 points. The percentage of correct responses for each knowledge area was classified as follows: high (≥90%), medium (70–89%), and low (≤69%) (Oh 2019; Shinde and Mohite 2024).

Data were collected from 10 March to 24 May 2023 by distributing the questionnaire to the nurses (N = 55) who registered for training through the training centre. The questionnaire was distributed by the training centre coordinator, who had no direct role in the training programme, minimizing bias. It was administered three times before and twice after implementing the blended learning approach. Participation was voluntary, and all participants received an informed consent form outlining the study's purpose, the data collection process, and the anonymity measures. Consent was confirmed through the completion and submission of the questionnaire. The questionnaire was anonymous and completed independently without supervision to prevent response bias. All 55 questionnaires were returned (100%), but only 50 (91%) were included in the analysis as incomplete responses were excluded to ensure data reliability and analytical accuracy.

3.4. Data analysis

Statistical data analysis was performed using IBM SPSS Statistics for Windows, version 29.0. The reliability of the questionnaire was assessed by calculating the Cronbach's alpha coefficient ($\alpha = 0.69$), indicating moderate internal consistency. Although this value falls below the commonly accepted threshold of 0.70, it is considered acceptable in the context of this study (Taber 2018). Descriptive statistics were used to summarize participants' demographic characteristics, hospital attributes, and hand hygiene practices. The chi-square test examined associations between hand hygiene knowledge and demographic factors. A p-value of < 0.05 was considered statistically significant.

3.5. Research ethics

The study adhered to the ethical principles of the Declaration of Helsinki (Shrestha and Dunn 2020), ensuring the protection of participants' rights and data confidentiality. The ethics committee approved the protocol before the study commenced. The study received approval from the Research Ethics Committee of the National Institute for Health Development (TAIEK) (TAIEK, Decision No. 867). The collected data did not include any personally identifiable information, ensuring the anonymity of the participants. Participants were informed that they could withdraw from the study at any time, emphasizing that participation was voluntary, and that non-participation would not result in negative consequences. Participants provided their consent by returning the completed questionnaire. To ensure anonymity, questionnaires were sent to participants via email, along with a link to the anonymous online survey tool LimeSurvey. The purpose and methods of the study were presented to participants at the beginning of the questionnaire to ensure their awareness and understanding of the study's context.

4. Results

4.1. Demographics

A total of 50 nurses (91%) participated in the study, all of whom were female. The highest percentage of participants was in the age group of 44–51 years, accounting for 24% of the sample. The average age of the participants was 46 years (SD = 13.654). The youngest participant was 23 years old, while the oldest was 75 years old. The nurses represented six departments. The most significant proportion came from the surgery department, with 16 nurses (32%), and the internal medicine department, with 16 nurses (32%). Seven nurses (14%) participated from the infectious diseases department

and seven nurses (14%) from the urology department. Three nurses (6%) were from the neurology department, while only one nurse (2%) was from the psychiatry department. No significant associations were identified between demographic variables and nurses' hand hygiene knowledge.

4.2. Nurses' knowledge before blended learning

According to the analysis, the percentage of correct responses among the nurses was 75%. According to the definition by Shinde and Mohite (2014) and Oh (2019), a score above 75% is considered a good knowledge level, 50–74% is classified as moderate, and a score below 50% is regarded as poor. The study included 50 nurses, 33 (66%) of whom had completed hand hygiene training within the past three years. Statistical analysis indicated that nurses who had undergone training had significantly better knowledge of hand antisepsis than those who had not received training. They understood that hand antisepsis is a quicker method for combating microorganisms than handwashing with soap and water ($\chi^2 = 4.766$, df = 1, p = 0.029) (see Table 1).

A total of 47.9% of nurses (n = 23) correctly identified that contaminated healthcare workers' hands are the primary route of microbial transmission between patients (question 14 (Q14)) (see Table 2). The remaining participants mistakenly considered airborne transmission, contaminated surfaces, or shared non-invasive medical devices, such as stethoscopes and blood pressure monitors, as the main risk factors. Additionally, 46% (n = 23) (Q15) of nurses recognized that the primary source of healthcare-associated infections is the patient's microbiota rather than the air or surfaces in the healthcare facility.

Before the training, nurses' awareness of the WHO 'My 5 Moments for Hand Hygiene' framework varied significantly. The highest awareness was observed for M1 (before touching a patient) (Q16a) and M2 (before an aseptic or clean procedure) (Q16d), with 90% (n = 45) and 86% (n = 43) of nurses correctly identifying their importance in patient protection. Similarly, adherence to M4 (after touching a patient) was very high, at 96% (n = 48) (Q17a), reflecting a stronger understanding of self-protection. However, awareness was critically low for M3 (after exposure to body fluids), with only 14% (n = 7) (Q16b) recognizing the necessity of immediate hand hygiene to prevent microbial transmission. Adherence to M5 (after contact with the patient's surroundings) was also insufficient, as only 26.5% (n = 13) (Q16c) acknowledged the role of environmental contamination in the spread of infection, leaving 72% (n = 36) unable to assess this risk adequately.

4.3. The impact of blended learning on nurses' awareness of the WHO 'My 5 Moments for Hand Hygiene'

The study results (Table 2) indicate that the blended learning-based training positively impacted nurses' awareness of the WHO 'My 5 Moments for Hand Hygiene', increasing the proportion of correct responses from 75% to 78%.

Prevention of microbial transmission to the patient: Awareness of M1 (before touching a patient) increased marginally (92%, n = 46, p = 0.727) (Q16a). A similar trend was observed for M2 (before an aseptic procedure), where knowledge improved slightly from 87.8% (n = 43) to 90% (n = 45, p = 0.722) (Q16d). In contrast, awareness of M3 (after exposure to body fluids) showed a more substantial improvement (14.3%, n = 7 → 22%, n = 11, p = 0.320) (Q16b), yet remained low, underscoring the need for more robust practical training methods. However, awareness of M5 (after contact with the patient's surroundings) declined from 26.5% (n = 13) to 22% (n = 11, p = 0.599) (Q16c), highlighting the training's inefficacy in this specific aspect.

Prevention of microbial transmission to healthcare workers: Awareness of M4 (after touching a patient) was already very high before training (98%, n = 48). It remained unchanged (p = 0.570) (Q17a), suggesting limitations in the training's impact on moments reinforced by habitual practice. In contrast, adherence to M5 (after contact with the patient's surroundings) improved significantly from 83.7% (n = 41) to 94% (n = 47, p = 0.102) (Q17d), indicating increased awareness. However, awareness of M3 (after exposure to body fluids) declined from 93.9% (n = 46) to 85.7% (n = 42, p = 0.182) (Q17b), suggesting potential confusion in interpreting training content or behavioural barriers. Awareness of M2 (before an aseptic procedure) increased from 26% (n = 13) to 42% (n = 21, p = 0.127) (Q17c), yet remained below the desired level, highlighting the need for additional interventions.

Statistically significant differences in knowledge of hand hygiene methods: Before training, 26 nurses (57.8%) correctly identified the necessity of handwashing after visible exposure to blood (M3), which increased to 40 nurses (85.1%) post-training (p = 0.004) (Q20f). Awareness of the required duration for hand antisepsis improved from 37 nurses (74%) to 46 (92%) (p = 0.016) (Q37). Additionally, more nurses recognized that sequential handwashing and antisepsis are not always necessary (92% post-training vs 78% pre-training, 46 vs 39 nurses) (p = 0.050) (Q18d).

Awareness of the effects of hand antiseptics and traditional handwashing on skin dryness also improved, with the proportion of correct responses increasing from 52% (n = 26)

Table 1. Differences in nurses' knowledge based on training received in the last three years

Statement	Previous training completion		No previous training completion	
	Correct answers	Wrong answers	Correct answers	Wrong answers
18a. Hand rubbing is more rapid for hand cleansing than handwashing	28 (84.8%)	5 (15.2%)	9 (56.3%)	7 (43.8%)
18c. Hand rubbing is more effective against germs than handwashing	28 (84.8%)	5 (15.2%)	9 (56.3%)	7 (43.8%)

Table 2. Nurses' knowledge of hand hygiene

Statement	Before the training			After the training			Chi-square statistic value	p-value
	Correct/Yes	False/No	Not answered	Correct/Yes	False/No	Not answered		
9. Do you regularly use hand antiseptic?	47 (94%)	1 (2%)	2	49 (98%)	1 (2%)	0	0.001	0.977
10. Which of the following is the primary route of cross-contamination with potentially harmful pathogens between patients in a healthcare facility? (Select only one answer.)	23 (46%)	25 (50%)	2	35 (70%)	14 (28%)	1	5.576	0.018
11. What is the primary source of germs associated with healthcare-associated infections? (Select only one answer.)	23 (46%)	27 (54%)	0	27 (54%)	23 (46%)	0	0.640	0.424
12. Does hand hygiene prevent the transmission of germs to the patient? (Before touching the patient)	45 (90%)	5 (10%)	0	46 (92%)	4 (8%)	0	0.122	0.727
13. Does hand hygiene prevent the transmission of germs to the patient? (Immediately after potential contact with body fluids)	7 (14%)	42 (84%)	1	11 (22%)	39 (78%)	0	0.990	0.320
14. Which of the following is the main route of cross-transmission of potentially harmful germs between patients in a healthcare facility?	23 (47.9%)	25 (52.1%)	2	35 (71.4%)	14 (28.6%)	1	5.576	0.018
15. What is the most frequent source of germs responsible for healthcare-associated infections?	23 (46%)	27 (54%)	0	27 (54%)	23 (46%)	0	0.640	0.424
16. Which of the following hand hygiene actions prevents the transmission of germs to the patient?								
16a. Before touching a patient	45 (90%)	5 (10%)	0	46 (92%)	4 (8%)	0	0.122	0.727
16b. Immediately after a risk of body fluid exposure	7 (14.3%)	42 (85.7%)	1	11 (22%)	39 (78%)	0	0.990	0.320
16c. After exposure to the immediate surroundings of a patient	13 (26.5%)	36 (73.5%)	1	11 (22%)	39 (78%)	0	0.277	0.599
16d. Immediately before a clean/aseptic procedure	43 (87.8%)	6 (12.2%)	1	45 (90%)	5 (10%)	0	0.126	0.722
17. Which of the following hand hygiene actions prevents the transmission of germs to the healthcare worker?								
17a. After touching a patient	48 (98%)	1 (2%)	1	48 (96%)	2 (4%)	0	0.323	0.570
17b. Immediately after a risk of body fluid exposure	46 (93.9%)	3 (6.1%)	1	42 (85.7%)	7 (14.3%)	1	1.782	0.182
17c. Immediately before a clean/aseptic procedure	13 (26%)	37 (74%)	0	21 (42%)	28 (56%)	1	4.129	0.127
17d. After exposure to the immediate surroundings of a patient	41 (83.7%)	8 (16.3%)	1	47 (94%)	3 (6%)	0	2.672	0.102

Continued on the next page

Table 2. *Continued*

Statement	Before the training			After the training			Chi-square statistic value	p-value
	Correct/Yes	False/No	Not answered	Correct/Yes	False/No	Not answered		
18. Which of the following statements on alcohol-based hand rub and hand washing with soap and water are true?								
18a. Hand rubbing is more rapid for hand cleansing than handwashing	37 (74%)	12 (24%)	1	37 (74%)	13 (26%)	0	1.040	0.595
18b. Hand rubbing causes skin dryness more than handwashing	26 (52%)	24 (48%)	0	34 (68%)	16 (32%)	0	2.667	0.102
18c. Hand rubbing is more effective against germs than handwashing	37 (75.5%)	12 (24.5%)	1	39 (78%)	11 (22)	0	0.086	0.769
18d. Handwashing and hand rubbing are recommended to be performed in sequence	39 (78%)	11 (22%)	0	46 (92%)	4 (8%)	0	3.843	0.050
19. What is the minimal time needed for an alcohol-based hand rub to kill most germs on your hands?	37 (74%)	13 (26%)	0	46 (92%)	3 (6%)	1	9.226	0.016
20. Which type of hand hygiene method is required in the following situations?								
20a. Before palpation of the abdomen	45 (93.8%)	3 (6.3%)	2	48 (96%)	2 (4%)	0	0.256	0.613
20b. Before giving an injection	46 (92%)	0 (0%)	4	44 (95.7%)	2 (4.3%)	4	2.044	0.153
20c. After emptying a bedpan	15 (35.7%)	27 (64.3%)	8	19 (41.3%)	27 (58.7%)	4	0.289	0.591
20d. After removing examination gloves	43 (91.5%)	4 (8.5%)	3	48 (98%)	1 (2%)	1	2.034	0.154
20e. After making a patient's bed	37 (78.7%)	10 (21.3%)	3	40 (83.3%)	8 (16.7%)	2	0.329	0.566
20f. After visible exposure to blood	26 (57.8%)	19 (42.2%)	5	40 (85.1%)	7 (14.9%)	3	8.369	0.004
21. Which of the following should be avoided, as associated with increased likelihood of colonization of hands with harmful germs?								
21a. Wearing jewellery	47 (95.9%)	2 (4.1%)	1	49 (100%)	0 (0%)	1	3.032	0.220
21b. Damaged skin	48 (98%)	1 (2%)	1	46 (93.9%)	3 (6.1%)	1	1.043	0.307
21c. Artificial fingernails	48 (98%)	1 (2%)	1	50 (100%)	0 (0%)	0	1.031	0.310
21d. Regular use of hand cream	37 (77.1%)	11 (23%)	2	45 (91.8%)	3 (6.1%)	2	6.342	0.042

to 68% (n = 34, p = 0.102) (Q18b). Awareness of emptying a bedpan improved from 15 (35.7%) to 19 (41.3%) (p = 0.591) (Q20c). 47 nurses (94%) (Q9) reported regularly using alcohol-based hand antiseptics during daily nursing activities.

5. Discussion

This pilot study aims to assess changes in nurses' knowledge of hand hygiene before and after the implementation of a blended learning method – combining an eight-hour practical simulation with an e-learning module – based on the World Health Organization's 'My 5 Moments for Hand Hygiene' framework, and to provide further scientific insight into the applicability of this educational approach. Previous studies (Martos-Cabrera et al. 2019; Nakamura et al. 2019; Halasa et al. 2020) have shown that blended learning is an effective method for increasing hand hygiene awareness, but its impact on knowledge retention may be inconsistent. The findings of this study confirm this – overall awareness improved, but knowledge acquisition remained inconsistent, with significant gaps becoming apparent in certain critical aspects.

Understanding of hand hygiene following contact with body fluids (M3) and before aseptic procedures (M2) showed significant improvement, confirming prior research that nurses typically demonstrate strong knowledge of M1 – hand hygiene before patient contact (Shinde and Mohite 2014; Soesanto 2018). Comprehension of microbial transmission within the patient's environment (M5) remained inadequate, confirming previous studies' consistent reporting of low levels of M5-related knowledge and adherence (Mestan 2019). This discrepancy suggests a cognitive bias where direct biological hazards are perceived as more critical than indirect contamination risks (White et al. 2015; Løyland et al. 2020; Kim and Jeong 2021). Such a bias poses a significant challenge to implementing the WHO 'My 5 Moments for Hand Hygiene' framework. The persistently low adherence to M5 underscores the potential for overlooked environmental reservoirs of pathogens, exacerbating the risk of healthcare-associated infections. Addressing this gap requires targeted educational interventions to emphasize indirect contamination pathways.

The study revealed a decline in knowledge after training, particularly regarding the selection of hand hygiene methods following contact with the patient's environment and bedpan emptying, although the difference was not statistically significant. This suggests that blended learning did not ensure knowledge retention and led to uncertainty in its application. Previous studies confirm that short-term interventions may temporarily increase awareness but do not guarantee long-term knowledge retention or practical implementation (McCutcheon et al. 2015; Martos-Cabrera et al. 2019). In contrast, systematic training integrating theory and practice is more effective (Seo et al. 2019; Nguyen et al. 2020). Simulation-based training is a crucial component of blended learning, enhancing confidence and adherence to hand hygiene protocols (Nakamura et al. 2019; Ashraf et al. 2021). Therefore, training should prioritize interactive, scenario-based methods to support knowledge acquisition and practical application.

This study has certain limitations. The WHO's (2009) 'Hand Hygiene Knowledge Questionnaire for Health Care Workers' was used as the assessment tool, translated and adapted to the Estonian context. While the questionnaire's reliability (Cronbach's alpha = 0.69) indicates its suitability for knowledge assessment, it also highlights the need for further development and refinement of the instrument to enhance its accuracy and reliability.

Furthermore, additional research is needed to analyse the factors influencing M5 knowledge and adherence, as previous studies have consistently shown that compliance with M5 remains low compared to the other WHO '5 Moments' categories. Investigating the impact of organizational factors, workload, and environmental conditions on hand hygiene adherence is essential to designing more effective and context-specific interventions that support long-term behavioural change.

6. Conclusion

The findings of this study confirm that the blended learning method is a suitable approach to improving nurses' knowledge of hand hygiene based on the WHO 'My 5 Moments for Hand Hygiene' framework. However, knowledge acquisition was not uniform across all the moments. Improvements were observed in M1, M2, M3, and M4, whereas adherence to M5 remained low, suggesting the possible underestimation of indirect infection risks. Additionally, prior training was found to play a significant role in the practical application of hand hygiene, as nurses who had recently completed training demonstrated a clearer understanding of the benefits of hand antisepsis over traditional handwashing. Statistically significant knowledge changes included understanding the necessity of handwashing when hands are visibly soiled, understanding the 20-second duration of antisepsis, and recognizing that handwashing and antisepsis do not always need to be used sequentially. A common misconception was also identified: some nurses believed that antiseptics cause more skin dryness than handwashing, highlighting the need for more precise and practice-oriented training methods.

The study emphasizes the need for continuous and evidence-based training to ensure long-term knowledge retention and support behavioural changes. The findings confirm that an effective training strategy should be multi-faceted, integrating theory, practice, and simulations to facilitate knowledge transfer to clinical practice. Particular attention should be given to improving M5 adherence as low compliance suggests cognitive and behavioural barriers that should be addressed through targeted training interventions.

Data availability statement

All data are available in the article.

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Põimõppe mõju õdede kätehügieeni teadmistele

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Pilootuuringus analüüsiti õdede kätehügieeni teadmisi enne ja pärast põimõppe rakendamist, tuginedes Maailma Terviseorganisatsiooni (WHO) raamistikule „Minu 5 kätehügieeni hetke". See raamistik on koolituste läbiviimisel oluline, kuna pakub selget struktuuri, aidates koolitajatel ja koolitatavatel keskenduda olulistele kätehügieeni aspektidele. Uuringu käigus koguti andmeid WHO kätehügieeni teadmiste küsimustiku abil. Tulemused näitasid, et teadlikkus kätehügieeni meetoditest on märgatavalt tõusnud. Samas ei täheldatud, et arusaamad kätehügieenist voodipoti tühjendamisel oleksid paranenud ning seega oli teadlikkus tervishoiutöötajate saastunud kätega seotud riskidest ebapiisav. Uuring näitab, et kätehügieeni õpetamisel on vajalik mitmekesine koolitus, mis võimaldab õdedel paremini mõista kätehügieeni põhimõtteid ning eristada olukordi, millal kasutada antiseptikume ja millal eelistada kätepesu. Seetõttu on oluline arendada tõenduspõhiseid haridusstrateegiaid, et parandada kätehügieeni praktikat ning suurendada patsiendi ohutust ja hoolduse kvaliteeti.