Journal of Rural Community Nursing Practice (JRCNP)
Volume 3 Issue 1, March 2025, pp 60-82
https://ebsina.or.id/journals/index.php/JRCNP
eISSN 2986-7401, pISSN 2986-8424

Evaluation of Hand Hygiene Practices and Educational Interventions Among Indonesian Nursing Students: An Analysis Using ATP Wipe Tests and Hand Hygiene Checkers

Mayumi Sato[1], Syahrul[2], Tantut Susanto[3], Fithria[4], Naoki Hokama[1], Ruka Saito[5], Andi Muhammad Fiqri Muslih Djaya[1], Hiroshi Sugimoto[1]

1 Department of Nursing, Faculty of Nursing, Niigata University of Health and Welfare, Japan
2 Department of Community Nursing, Faculty of Nursing, Hasanuddin University, Indonesia
3 Department of Community Family and Geriatric Nursing, Faculty of Nursing, Jember University, Indonesia
4 Department of Public Health, Haluoleo University, Indonesia
5 Faculty of Health Sciences, Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University, Japan

Correspondence
Mayumi Sato
Faculty of Nursing, Department of Nursing, Niigata University of Health and Welfare
1398 Shimami-cho, Kita-ku, Niigata-shi, Niigata, Japan, 950-3198
E-mail: mayumi-sato@nuhw.ac.jp

Article History
Submitted: 19-02-2025
Revised: 14-03-2025
Accepted: 15-03-2025

ABSTRACT

Background: Infectious diseases, including dengue fever and waterborne infections, remain major public health concerns in Indonesia. Hand hygiene is essential for reducing healthcare-associated infections; however, nursing students often fail to practice it effectively despite having sufficient knowledge. **Purpose:** The present study evaluated the implementation of hand hygiene among Indonesian nursing students, assessed their adherence to the "Five Moments for Hand Hygiene" during clinical training, and examined the necessity for educational improvements using a hand hygiene checker and ATP swab testing. **Methods:** A cross-sectional study was conducted among nursing students from three national universities in Indonesia. Data were collected through a questionnaire survey on hand hygiene knowledge and practices, self-reported adherence to the 'Five Moments for Hand Hygiene' during clinical training, and an objective evaluation using a hand hygiene checker and ATP swab testing. **Results:** The majority of students understood hand hygiene techniques; however, 70% failed to meet the WHO recommended handwashing duration. Over 30% of students found it challenging to perform hand hygiene before patient contact and after touching objects in the patient's surroundings. The hand hygiene checker revealed residual contamination on the nails and fingertips, while ATP swab testing showed that 60% of students did not meet the standard threshold. **Conclusions:** Despite their knowledge, nursing students face challenges in implementing the proper hand hygiene practices. Knowledge alone is insufficient; practical education with visual and numerical feedback is essential. Training with hand hygiene checkers and ATP swab testing can improve self-assessment skills and enhance adherence to hand hygiene protocols.

KEYWORDS

ATP swab testing, Hand hygiene, Hand hygiene checker, Handwashing education, Nursing student

How to cite:
Sato, M., Syahrul, Susanto, T., Fithria, Hokama, N., Saito, R., Djaya, A. M. F. M., & Sugimoto, H. (2025). Evaluation of Hand Hygiene Practices and Educational Interventions Among Indonesian Nursing Students: An Analysis Using ATP Wipe Tests and Hand Hygiene Checkers. Journal of Rural Community Nursing Practice. 3(1), 60-82. https://doi.org/10.58545/jrcnp.v3i1.476

1. BACKGROUND

The World Health Organization (WHO) estimates that 15% of patients in low- and middle-income countries contract at least one healthcare-associated infection (HAI) during hospitalization (WHO, 2022). HAIs pose a serious issue, leading to prolonged hospital stays, increased medical costs, and higher mortality rates. One of the primary causes of HAIs is inadequate hand hygiene (HH) (Kohra et al., 2004; Osuka, 2005b; Pittet et al., 2000). Proper HH based on the WHO's "Five Moments for Hand Hygiene" is a fundamental measure for infection prevention by healthcare professionals (WHO, 2009).

In Indonesia, even before the COVID-19 pandemic, various infectious diseases had been significant public health concerns, including dengue fever, avian influenza, infections caused by unsanitary drinking water (Itagaki, 2009), waterborne diseases resulting from flooding (Fukushi, 2014), norovirus infections, and rotavirus infections (Nirwati et al., 2019). Acute gastroenteritis (acute diarrhea) has been identified as a major factor contributing to the high mortality rate among children younger than five years (Shinoda, 2019; Walker et al., 2013), highlighting the urgent need to strengthen infection prevention measures.

Amid these challenges, the COVID-19 pandemic in Indonesia emphasized the importance of mask-wearing and handwashing (Kaneko, 2021), and HAIs became a critical issue in medical institutions (Furuse et al., 2020; Taguchi et al., 2020). However, enhanced infection control measures during the pandemic led to a renewed recognition of the importance of HH, resulting in strengthened HH education for nursing students (Fujita, 2021; Utsumi, 2024).

Nursing students frequently come into contact with infectious disease patients and immunocompromised individuals during clinical training, making proper HH practices essential. However, previous studies reported that while nursing students possess knowledge of infection prevention, they do not always practice appropriate HH (Ohtake et al., 2021; Sato & Saito, 2019). Studies on Indonesian nursing students have also indicated that despite demonstrating high levels of knowledge and a positive attitude towards HH and infection prevention during the COVID-19 pandemic, they did not adequately implement preventive behaviors, such as wearing masks in public places and maintaining social

distancing (Bani et al., 2023). These findings suggest that possessing knowledge alone may not necessarily lead to improved adherence to HH practices (Miwaki, 2003).

Recent studies on HH in Indonesia have primarily analyzed the relationships between knowledge, attitudes, and implementation using questionnaire surveys (Bani et al., 2023; Palaz & Erbas, 2025; Santosaningsih et al., 2017). However, self-reported surveys are prone to bias, making it difficult to accurately assess actual HH practices.

Therefore, the present study investigated the actual state of daily HH and infection prevention among Indonesian nursing students during the COVID-19 pandemic as well as their adherence to the "Five Moments for Hand Hygiene" during clinical training. Furthermore, objective evaluations were conducted using a HH checker and ATP swab testing to examine changes in HH practices. Through these investigations, this study examined effective HH education methods tailored to Indonesian nursing students.

2. METHODS

Design

Th This study adopted a mixed-methods research design, combining a quantitative survey-based study with a quasi-experimental approach.

Sample

The sample of this study were nursing students enrolled in the nursing faculties of three national universities in Indonesia. This study was conducted using international exchange and academic cooperative relationships. Utilizing existing memorandum of understandings (MOUs), universities were selected that could feasibly conduct the study. This ensured the smoot progress of the study and reliability of the data. After explaining the study's purpose and obtaining informed consent, 637 students participated in the questionnaire survey. Among them, 25 students underwent ATP swab testing and 26 participated in the residual contamination assessment using a HH checker.

Data collection

1) Questionnaire survey

Six items regarding daily infection prevention behaviors among nursing students were assessed using a binary response format ("Yes" or "No"). Five items on HH practices at different daily life moments were evaluated using three response options: "Alcohol-based hand

sanitizer", "Running water only", and "Soap and running water". Among the three items related to HH methods, handwashing duration was measured using five-time intervals ranging from 10 to 60 seconds. Additionally, the study examined adherence to the "Five Moments for Hand Hygiene" during clinical training and examined the reasons for difficulties with its implementation. The survey was conducted as an anonymous web-based questionnaire using Google Forms, designed to be completed within approximately 10 to 15 minutes. Participants were informed about the purpose of the study and were assured that their responses would not affect their academic evaluations before providing their consent.

2) Residual contamination assessment using the HH checker

Twenty-six nursing students participated in the handwashing assessment using the SARAYA Handwashing Checker LED (Saraya, n.d.). After applying a special fluorescent lotion, students performed their usual HH routine. A blacklight was then used to identify areas with residual contamination. The evaluation covered 20 specific areas based on the WHO HH procedure, including the dorsal side of the hand (nails/fingertips, interdigital spaces, thumb, little finger, and dorsum) and the palmar side (fingertips, interdigital spaces, thumb, little finger, and palm).

3) ATP (A3 Method) Swab Testing (KIKKoman®, Kikkoman Biochemifa Co., Ltd.)

To quantitatively assess microbial reduction before and after HH, ATP swab testing was conducted on 25 nursing students. The test involved swabbing the entire hand with a specialized swab before and after HH and measuring ATP bioluminescence (Relative Light Units, RLU) using a luminometer. ATP is an energy-carrying molecule found in biological organic matter, and higher RLU values indicate greater contamination levels. In this study, the post-HH threshold was set at ≤2,000 RLU, as recommended by Kikkoman (Kikkoman, n.d.).

Validity and reliability

This study ensured content validity by designing questionnaire items based on the WHO's "Five Moments for Hand Hygiene". Additionally, objective evaluations using ATP swab testing and the HH checker were incorporated to measure HH practices from multiple perspectives, enhancing construct validity.

A pilot test of the questionnaire was conducted to assess comprehension and response consistency. ATP swab testing was performed following standardized procedures to ensure the reproducibility of measurement results.

To enhance the credibility of the study, triangulation was conducted by integrating data from the questionnaire survey, ATP testing, and HH checker assessments. This approach ensured data objectivity and improved the transparency of the research.

Data analysis

1) Questionnaire survey analysis

Descriptive statistics were used to identify overall trends in HH questionnaire results. Key items analyzed included concerns about COVID-19 infection, the frequency of alcohol-based sanitizer and soap use in daily life, hand drying methods after washing, and the frequency of mask-wearing and replacement. The chi-square test was conducted to compare these variables between students with and without clinical training experience. Regarding the handwashing duration, students were divided into two groups based on the WHO-recommended 40–60 seconds: those washing for less than 40 seconds and those washing for 40–60 seconds. The Mann-Whitney U test was then performed to compare these groups. All quantitative analyses were completed using Statistical Package for the Social Sciences (SPSS) version29 using standardized estimates.

Additionally, qualitative descriptions of difficulties encountered by students in implementing the "Five Moments for Hand Hygiene" during clinical training were analyzed using KH Coder (a co-occurrence network analysis) for text mining (Higuchi, 2020; Higuchi et al, 2022).

2) HH checker analysis

The percentage of residual contamination was calculated based on the WHO-recommended HH procedure. The analysis focused on 20 areas across both hands, including the dorsal side (nails/fingertips, interdigital spaces, thumb, little finger, and dorsum) and palmar side (fingertips, interdigital spaces, thumb, little finger, and palm). Areas with the highest contamination levels were identified, providing a visual assessment of nursing students' HH practices.

3) ATP swab test analysis

In ATP swab testing, mean RLU values before and after HH were calculated, and the reduction rate was compared.

Additionally, the percentage of students who met the hygiene standard threshold of ≤2,000 RLU (Kikkoman, n.d.) was analyzed to evaluate the rate of adherence to proper HH practices.

Ethical consideration

Participation was voluntary and no disadvantages were imposed on participants. Since the survey was conducted anonymously via a web-based questionnaire, participants were informed that withdrawal was not possible after submission. Additionally, no adverse effects associated with the fluorescent lotion used in the HH checker have been reported, and participants were informed about compensation in the event of any hand-related issues. Furthermore, all results were used solely for research purposes, with careful measures taken to ensure that individuals and institutions remained unidentifiable. The present study was conducted with the approval of the Ethics Committees of Niigata University of Health and Welfare and Hasanuddin University (Approval Numbers: 19101-230707, 14823105023).

3. RESULTS

Participant characteristics

Responses were obtained from 477 nursing students enrolled in the nursing faculties of Indonesian universities, with a response rate of 70%. Among the respondents, 391 (87.5%) were female and 56 (12.5%) were male. Of these, 224 students (50.1%) had clinical training experience, comprising 196 females (43.8%) and 28 males (6.3%). The remaining 223 students (49.9%) had no clinical training experience, including 195 females (43.6%) and 28 males (6.3%). The overall response rate was 70%, and although some responses were incomplete, all valid responses were included in the analysis, ensuring a 100% effective response rate. Additionally, among students without clinical training experience, 26 participated in the HH checker assessment and 25 in the ATP swab testing.

Hand hygiene and infection prevention practices among nursing students (Table 1)

1) Concerns about COVID-19 infection

A total of 75.6% of students reported feeling anxious about COVID-19 infection, while 24.4% did not experience any concerns. Among students with clinical training experience, 69.2% expressed infection-related anxiety, whereas 82.1% of students

without clinical training experience reported feeling anxious. The level of infection-related anxiety was significantly higher among students without clinical training experience (p=0.002).

Table 1. Daily hand hygiene and infection prevention behaviors of nursing students (N=447)

	Total n (%)	Students with clinical training experience (n=224) n (%)	Students without clinical training experience (n=223) n (%)	p-value
Anxiety about COVID-19 infection				
Yes	338 (75.6)	155 (69.2)	183 (82.1)	0.002*
No	109 (24.4)	69 (30.8)	40 (17.9)	
Use of an alcohol-based hand sanitizer in daily life				
Yes	377 (84.3)	202 (90.2)	175 (78.5)	0.001**
No	70 (15.7)	22 (9.8)	48 (21.5)	
Use of soap for handwashing in daily life				
Yes	257 (57.5)	135 (60.3)	122 (54.7)	0.252
No	190 (42.5)	89 (39.7)	101 (45.3)	
Hand drying method after handwashing				
Paper towel	344 (77.0)	176 (78.6)	168 (75.3)	0.434
Air drying	103 (23.0)	48 (21.4)	55 (24.7)	
Mask-wearing during COVID-19				
Always	382 (85.5)	204 (91.1)	178 (79.8)	0.001**
Rarely	65 (14.5)	20 (8.9)	45 (20.2)	
Mask replacement frequency during COVID-19				
Changed daily	297 (66.4)	176 (78.6)	174 (78.0)	0.909
Did not change	56 (12.5)	48 (21.4)	49 (22.0)	

*Data were analyzed using the χ^2 test, Fisher's exact test, and Haberman's residual analysis (**p<.01, *p<.05)*

2) Hand hygiene practices

Regarding HH methods, 84.3% of students reported using alcohol-based hand sanitizers in their daily lives. Among them, 90.2% of students with clinical training experience used alcohol-based sanitizers, which was significantly higher than the 78.5% of students without clinical training experience (p=0.001). On the other hand, only 57.5% of students used soap and running water, indicating a low implementation rate. Regarding hand drying after washing, 77.0% of students used paper towels, while 23.0% opted for natural air drying. Concerning mask usage during the COVID-19 pandemic, 85.5% of students reported "always wearing a mask". Among them, 91.1% of students with clinical training experience adhered to consistent mask usage, which was significantly higher than

the 79.8% of students without clinical training experience (p=0.001). Regarding the frequency of mask replacement, 85.5% of students reported changing their masks daily. However, 12.5% did not regularly replace their masks. Notably, while 85.5% of students reported wearing masks during the COVID-19 pandemic, only 66.4% replaced their masks with a new one daily. Among those who wore masks, 22.2% did not change them daily despite constantly wearing them.

Hand hygiene practices at different daily life moments (Table 2)

An analysis of HH implementation rates at different moments in daily life revealed that 86.8% of students used soap and running water when their hands were visibly dirty. Among them, 91.5% of students with clinical training experience adhered to this practice, which was significantly higher than the 82.0% of students without clinical training experience (p=0.01). Additionally, 74.4% of students used alcohol-based hand sanitizers when they were short on time. This practice was significantly more common among students with clinical training experience (84.8%) than among those without (63.7%) (p=0.001). Hand hygiene implementation rates before and after meals, as well as after using the toilet, were high (ranging from 79.2 to 92.6%), indicating that most students followed proper HH practices. Specifically, before meals, 83.0% of students with clinical training experience used soap and running water, which was significantly higher than the 75.3% of students without clinical training experience (p=0.047). However, a larger number of students used only running water. Before meals, 16.3% of all students opted for running water only, while 4.5% used alcohol-based hand sanitizers.

Table 2. Hand hygiene at different daily life moments (N=447). *(*Continue to page 68)*

	Total n (%)	Students with clinical training experience (n=224) n (%)	Students without clinical training experience (n=223) n (%)	p-value
When hands are visibly dirty				
Alcohol-based sanitizer	37 (8.3)	11 (4.9)	26 (11.7)	
Running water only	22 (4.9)	8 (3.6)	14 (6.3)	0.011*
Soap with running water	388 (86.8)	205 (91.5)*	183 (82.1)*	
When short on time				
Alcohol-based sanitizer	332 (74.3)	190 (84.8)**	142 (63.7)**	
Running water only	83 (18.6)	20 (8.9)**	63 (28.3)**	0.001**
Soap with running water	32 (7.2)	14 (6.3)	18 (8.1)	

	Total n (%)	Students with clinical training experience (n=224) n (%)	Students without clinical training experience (n=223) n (%)	p-value
After using the toilet				
Alcohol-based sanitizer	36 (8.1)	17 (7.6)	19 (8.5)	
Running water only	34 (7.6)	14 (6.3)	20 (9.0)	0.500
Soap with running water	377 (84.3)	193 (86.2)	184 (82.5)	
Before meals				
Alcohol-based sanitizer	20 (4.5)	11 (4.9)	9 (4.0)	
Running water only	73 (16.3)	27 (12.1)*	46 (20.6)*	0.047*
Soap with running water	354 (79.2)	186 (83.0)*	168 (75.3)*	
After meals				
Alcohol-based sanitizer	16 (3.6)	6 (2.7)	10 (4.5)	
Running water only	17 (3.8)	9 (4.0)	8 (3.6)	.575
Soap with running water	414 (92.6)	209 (93.3)	205 (91.9)	

*Data were analyzed using the χ^2 test, Fisher's exact test, and Haberman's residual analysis (**p<.01, *p<.05)*

Hand hygiene methods (Table 3)

Regarding knowledge of HH methods, 99.8% of all students reported being aware of proper HH practices, while only 0.2% indicated a lack of knowledge. Additionally, 96.0% of students understood the difference between alcohol-based sanitizers and soap with running water. Among them, 98.2% of students with clinical training experience recognized this difference, which was significantly higher than the 93.7% of students without clinical training experience (p=0.017), indicating a greater level of awareness among the former.

Table 3. Hand hygiene methods (N=447)

	Total n (%)	Students with clinical training experience (n=224) n (%)	Students without clinical training experience (n=223) n (%)	p-value
Do you know how to perform hand hygiene?				
Yes	446 (99.8)	223 (99.6)	223 (100.0)	-
No	1 (0.2)	1 (0.4)	0 (0.0)	
Do you know the difference between an alcohol-based sanitizer and soap with running water?				
Yes	429 (96.0)	220 (98.2)	209 (93.7)	0.017*
No	18 (4.0)	4 (1.8)	14 (6.3)	
Hand hygiene duration				
40–60 seconds	135 (30.2)	86 (38.4)	49 (22.0)	.001**
Less than 40 seconds	312 (69.8)	138 (61.6)	174 (78.0)	

*Data were analyzed using the χ^2 test, Fisher's exact test, and Haberman's residual analysis (**p<.01, *p<.05)*

Regarding the duration of HH, the mean rank for students with clinical training experience (254.52) was significantly higher than that for students without clinical training experience (193.35) (U=18140.0, Z=-5.086, p<0.001), suggesting that students with clinical training spent more time on HH. Overall, 30.2% of students reported performing HH for 40–60 seconds. This percentage was higher among students with clinical training experience (38.4%) than among those without (22.0%). Conversely, 69.8% of students reported spending less than 40 seconds on HH, with 61.6% of students with clinical training experience and 78.0% of students without training falling into this category, indicating that students without clinical training spent less time on HH (p=0.001).

Residual contamination assessment using the HH checker (Table 4)

The HH checker assessment revealed that all nursing students had at least one area with residual contamination. Notably, the residual contamination rate for fingernails, fingertips, and the index to little fingers on the dorsal side of the hand was >90%, with no significant difference between the left and right hands. Although some residual contamination was observed on the fingertips and interdigital spaces on the palmar side, the contamination rates for the thumb and entire palm were low.

Table 4. Residual contamination rates by hand region (N=26)

Hand region		Right hand	Left hand
Dorsal side	Nails/fingertips	96.2%	96.2%
	Interdigital spaces	61.5%	69.2%
	Thumb	80.8%	84.6%
	Index to little finger	96.2%	92.3%
	Dorsum of the hand	38.5%	38.5%
Palmar side	Fingertips	80.8%	80.8%
	Interdigital spaces	34.6%	38.5%
	Thumb	15.4%	11.5%
	Index to little finger	65.4%	73.1%
	Palm	19.2%	23.1%

ATP swab test results

The average ATP RLU value was 18,226.88 ± 12,984.4 (range: 3,942–58,225) before and decreased to 3,958.52 ± 4,361.7 (range of 862–20,248) after HH. While all nursing students showed a reduction in ATP RLU values after HH, only 40% achieved a lower value than the hygienic standard of ≤2,000 RLU.

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https://ebsina.or.id/journals/index.php/JRCNP
eISSN 2986-7401, pISSN 2986-8424

Adherence to the "Five Moments for Hand Hygiene" (Table 5)

The highest percentage of students who reported "always performing" HH was observed for the following moments: "I: before touching a patient (77.7%)", "II: before clean/aseptic procedures (92.9%)", "III: after potential exposure to bodily fluids (98.7%)", "IV: after touching a patient (97.3%)", and "V: after touching patient surroundings (84.8%)".

Table 5. Co-occurrence network analysis of reasons for non-adherence to hand hygiene

Main cluster	Main category	Frequent words	Example codes
I: before touching a patient (Cluster 6)	Lack of awareness	Forget (29), Patient (24), Handwashing (19), Before (11), Touch/Go/Hurry (7)	1. I forget to wash my hands before touching a patient when I'm in a hurry. 2. I believe my hands are clean so I forget to wash them before going to the patient. 3. There are many patients so I tend to forget.
	Lack of knowledge	Gloves (8), Use (7), Emergency/Must (3), Wear/Action/Case (2)	1. I use gloves when touching a patient. 2. I think my hands are clean because I am wearing gloves.
		Hand (13), Clean (8), Myself (4), Wash/Think (3)	1. I don't feel my hands are dirty. 2. I think my hands are already clean.
	Environmental constraints	Usually (4), Suddenly/Reach (2)	1. Sometimes I have to go to a patient suddenly and can't reach the hand sanitizer. 2. I'm usually in a hurry and can't easily access a hand sanitizer so I forget.
V: after touching patient surroundings (Cluster 6)	Lack of awareness	Forget (23), Hand (16), Wash (11), Touch (4), Think (3), Dirt (2)	1. Since I do not touch the patient directly, I forget to wash my hands. 2. After touching the patient's surroundings, I continue writing and forget to wash my hands.
	Lack of knowledge	Patient (38), Touch (16), Environment (14), Directly (8)	1. I do not wash my hands often because I do not touch the patient directly. 2. I think the patient's environment is not dirty. 3. I am in the patient's environment, but since I do not touch the patient directly, I don't wash my hands.

On the other hand, the most frequently reported challenges in adherence were "I: before touching a patient (39.9%)" and "V: after touching patient surroundings (32.9%)". To further analyze the factors contributing to these difficulties, a co-occurrence network analysis using KH Coder was conducted for the moments "I: before

touching a patient" and "V: after touching patient surroundings".

In the case of "I: before touching a patient", and 796 words were extracted with 337 instances of usage. Among them, 167 unique words appeared and were used 112 times. Three major clusters were identified: lack of awareness, lack of knowledge, and environmental constraints. Representative responses included statements such as "I forget to perform HH because I am in a hurry", "I believe my hands are clean because I am wearing gloves", and "I cannot access hand sanitizer easily". Regarding "V: after touching patient surroundings", 733 words were extracted with 314 instances of usage. Among them, 149 unique words appeared and were used 98 times. Two main clusters were identified: lack of awareness and lack of knowledge. Representative responses included statements such as "I did not directly touch the patient", "I forget to wash my hands after touching the surroundings", and "I think the patient's environment is not dirty".

4. DISCUSSION

The present study examined the HH practices of Indonesian nursing students during the COVID-19 pandemic, with a focus on their daily HH habits, adherence to the "Five Moments for Hand Hygiene" during clinical training, and evaluations using a HH checker and ATP swab testing. The results obtained revealed that while Indonesian nursing students possessed a certain level of knowledge and practiced HH, several challenges were identified.

Infection prevention practices in daily life

Regarding the daily HH and infection prevention behaviors of Indonesian nursing students during the COVID-19 pandemic, approximately 80% of students reported using alcohol-based hand sanitizers and wearing masks. Additionally, students demonstrated selective HH behaviors based on daily life moments, such as washing their hands with soap and running water when their hands were visibly dirty, after using the toilet, and before and after meals. These results suggest that visually apparent risks (such as visible dirt) and culturally ingrained hygiene awareness (e.g., washing hands after using the toilet) may serve as key factors in promoting HH practices.

However, in contrast to these results, only 57.5% of students reported regularly using soap for HH in their daily lives. One possible reason for this is that Indonesia has the world's largest Muslim population, with approximately 90% of its citizens adhering to

Islam. As a result, many nursing students have the habit of performing Wudu, which is a ritual purification that involves washing the hands, face, and other parts of the body with running water five times a day before prayer (Shalat). This cultural practice may have affected students' perception of HH, leading them to not consider every instance of handwashing as involving soap. Consequently, despite washing their hands frequently, they may not have used soap every time, which may explain the lower reported rate of soap use. On the other hand, among students who did not fully implement infection prevention measures, behaviors such as allowing hands to air-dry after washing and not replacing masks daily were observed. These results indicate a lack of habituation in infection prevention behaviors and insufficient awareness of proper infection control practices.

Additionally, nursing students who had participated in clinical training showed significantly higher adherence rates to infection prevention behaviors, including the use of alcohol-based hand sanitizers, wearing masks, and performing HH when their hands were visibly dirty, when they were short on time, and before meals. These students also exhibited lower levels of psychological anxiety regarding COVID-19 infection. These results suggest that the knowledge and experience gained through clinical training during the COVID-19 crisis contributed to the adoption of infection prevention behaviors, which has been reported in other studies (Nakagawa & Sasaki, 2021). Therefore, it is likely that students engaged in clinical training developed a more realistic understanding of infection risks through firsthand experiences in healthcare settings, which may have helped reduce vague anxiety about COVID-19.

On the other hand, students without clinical training experience were more likely to feel anxious about COVID-19 infection. A previous study reported that individuals with lower adherence to preventive health behaviors were more likely to experience COVID-19-related anxiety (Sun et al., 2020). Similarly, the present results showed that students without clinical experience had lower rates of preventive infection behaviors and were more prone to anxiety. Therefore, it is important to implement educational interventions that encourage the habituation of infection prevention behaviors among inexperienced students. Additionally, providing appropriate information is important to reduce anxiety.

A total of 99.8% of students reported understanding HH methods, and 96.0% demonstrated an awareness of the difference between alcohol-based hand sanitizers and soap with running water. However, >20% of students stated that they allowed their hands to air-dry after HH, and approximately 70% spent less than 40 seconds on handwashing, failing to meet the WHO's recommended standards. Although knowledge-based questions yielded high accuracy rates, these results, combined with previous findings, indicate a discrepancy between knowledge and the actual practice of proper HH. Similar challenges have already been reported (Avşar et al., 2015; Kakeya, 2006; Sugita et al., 2005; Tanahashi et al., 2009), highlighting the need for more practical education in HH among nursing students.

Furthermore, previous studies demonstrated that residual contamination was most commonly found on the fingernails, fingertips, and interdigital spaces on the dorsal side of the hand (Terashima et al., 2009; Yamada et al., 2009). This is consistent with the present results showing an exceptionally high residual contamination rate of approximately 96% on the fingernails and fingertips of the dorsal side. Additionally, a certain percentage of residual contamination was observed on the palmar side. However, the use of the HH checker allowed students to visually recognize the inadequacy of their HH practices. As a result, during the second assessment, residual contamination was reduced, suggesting that feedback from the HH checker contributed to behavioral improvements.

ATP swab testing revealed that even after HH, 60% of students had ATP RLU values exceeding the hygienic threshold of 2,000 RLU. This result highlights that proper HH was not being effectively performed by a significant percentage of students.

Since ATP testing provides quantifiable data within approximately 10 seconds after swabbing, it has been reported as an effective method for immediately evaluating the effectiveness of HH (Kurosu, 2019). Additionally, previous studies indicated that ATP values were generally better in the second measurement than in the first (Yamada et al., 2009), which was also observed in the present study. These findings and the present results suggest that numerical feedback enhances the learning effect and improves the accuracy of a self-assessment.

Furthermore, the present study found that many students relied solely on visual

inspections to assess the cleanliness of their hands. However, ATP testing revealed that 60% of students did not meet the hygiene standard, highlighting the inaccuracy of a self-assessment. The provision of objective data is expected to help students develop a more detailed understanding of the importance of HH and improve the quality of their practice. Previous studies also reported the effectiveness of educational tools that enhance awareness of HH and provide visual confirmation of its efficacy (Banno et al., 2010; Iigusa et al., 2012; Kato, 2015; Nishioka et al., 2010; Terashima et al., 2009). Based on these findings, training programs incorporating HH checker and ATP testing may serve as a motivational tool, allowing students to objectively assess their HH status and acquire proper HH practices.

Adherence to the "Five Moments for Hand Hygiene" among nursing students in clinical training

Regarding the "Five Moments for Hand Hygiene", >75% of students reported that they "always perform" HH. However, to minimize bias, the survey also asked students which moments were difficult to adhere to. Approximately 30% of students indicated that they struggled with "I: before touching a patient" and "V: after touching patient surroundings". One possible reason for this discrepancy is that adherence is generally higher in situations where nurses provide direct supervision. Moments such as "II: before clean/aseptic procedures" and "III: after potential exposure to bodily fluids" involve frequent HH under the guidance of nurses, making adherence nearly mandatory. Additionally, adherence to "IV: after touching a patient" may be higher due to an increased awareness of self-protection against infection.

On the other hand, adherence rates slightly decreased in situations where students had to make independent decisions. "I: before touching a patient" and "V: after touching patient surroundings" are the moments in which students are most frequently involved, requiring them to independently assess the necessity of HH. As a result, situations such as "I thought my hands were clean because I was wearing gloves" or "I forgot to perform hand hygiene" were more likely to occur.

In the present study, an analysis of free-text responses regarding difficulties in performing HH revealed that the primary barriers were a lack of awareness, a lack of knowledge, and environmental constraints. These results are consistent with previous findings, which identified insufficient

resources, improper glove use, workload, and lack of education as factors hindering adherence to HH practices (Osuka, 2005a; Santosaningsih et al., 2017). Additionally, it has been reported that students' adherence rates are affected by low compliance with infection prevention measures among healthcare professionals and a shortage of HH supplies (Palaz & Erbas, 2025). Furthermore, the HH practices of nurses may significantly impact students' behaviors (Asfarada et al., 2024). The present results are consistent with these findings.

Therefore, to improve nursing students' adherence to HH, education must go beyond simply providing knowledge and focus on fostering practical application. The effectiveness of practical education has been reported in previous studies, with simulation-based training enhancing adherence to HH in real clinical settings (Takeshita et al., 2021). Additionally, it is crucial to emphasize that HH remains necessary even when wearing gloves because it may prevent misconceptions. Moreover, environmental improvements, such as the appropriate placement of hand sanitizers, have been suggested to contribute to better adherence rates (Nishioka et al., 2010). By integrating these educational approaches, it is essential to create an environment where students may independently and proactively perform proper HH practices.

Educational implications

The present results suggest that improving nursing students' adherence to HH requires visual feedback, awareness of the timing of HH, and continuous education. Visual feedback has the potential to enhance HH practices. In this study, presenting students with ATP swab test results generally improved adherence. Additionally, raising awareness of the timing of HH is essential. This study revealed low adherence rates for "before touching a patient" and "after touching patient surroundings," highlighting the need for practical training focused on these specific moments.

Furthermore, continuous education is necessary to promote the habitual practice of HH. Behavioral change is difficult to achieve through short-term lectures alone, making long-term programs that include clinical training essential for ensuring sustained adherence. By integrating these educational approaches, nursing students' HH practices are expected to improve.

Limitations of the study

This study has several limitations that need to be addressed. Since the questionnaire survey relied on self-reported data, there is a possibility that HH adherence rates were overestimated from actual practices. Additionally, during the implementation of the HH checker and ATP swab testing, students may have performed HH more consciously than their normal practice. Furthermore, while this study evaluated the state of HH practices, it did not examine the long-term impact of these tools on adherence rates.

5. CONCLUSION

The present study investigated the HH practices of Indonesian nursing students and found that while their knowledge was high, there were challenges with practical application. A total of 99.8% of students understood HH methods, and 96.0% recognized the difference between alcohol-based sanitizers and soap with running water. However, only 30.2% of students met the WHO-recommended HH duration of 40–60 seconds, while approximately 70% performed HH for less than 40 seconds.

Additionally, >90% of students reported that they "always perform hand hygiene", while >30% found it difficult to adhere to HH "I: before touching a patient" and "V: after touching patient surroundings". The main factors contributing to these difficulties were identified as a lack of awareness, a lack of knowledge, and environmental constraints.

Furthermore, the HH checker revealed that residual contamination rates on fingernails, fingertips, and interdigital spaces were >90%, with inadequate handwashing frequently occurring when gloves were worn. ATP swab testing also showed that even after HH, 60% of students did not meet the hygiene standard of ≤2,000 RLU.

Collectively, even if they have knowledge of hand hygiene, it is possible that they are doing it in their own way. It is also possible that they are doing hand hygiene without remembering the concept of preventing infection. These findings confirm that practical education with visual and numerical feedback is key to improving HH adherence.

ACKNOWLEDGMENT

We would like to express our deepest gratitude to the nursing faculties of Hasanuddin University, Jember University, and Haluoleo University for their cooperation with this study.

AUTHOR CONTRIBUTIONS

Substantial contributions to conception and analysis: Mayumi Sato, Naoki Hokama, Ruka Saito, and Hiroshi Sugimoto. Data collection: Mayumi Sato, Ruka Saito, Syahrul, Tantut Susanto, Fithria, and Andi Muhammad Fiqri Muslih Djaya. Writing, and Manuscript revisions: Mayumi Sato and Hiroshi Sugimoto.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study.

FUNDING

This study was conducted without any specific funding support.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article.

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