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The use of hand scanner to enhance hand hygiene practice among nursing students: A single-blinded feasibility study

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1. Background

Hand hygiene (HH) has been recognized as the most effective measure for reducing healthcare-associated infections in the clinical setting (Park et al., 2014). Alcohol-based hand rub (ABHR) is recommended over soap and water for routine HH practice, unless hands are visibly dirty or soiled with blood or other body fluids (Duong et al., 2017). HH compliance in the clinical setting is usually governed by the 'Five Moments of Hand Hygiene' recommended by the World Health Organization (WHO, 2009). However, even when HH is performed at appropriate 'moments', the effectiveness of the HH technique remains a concern (Lehotsky et al., 2015). Park et al. (2014) reported that appropriate hand surface coverage was observed in < 10.0% of HH procedures during hand rubbing.

Among various approaches for monitoring HH compliance, direct observation of health care workers (HCWs) conducted by trained infection control personnel is considered as the current gold standard (Boyce, 2008; Jeanes et al., 2015; Pineles et al., 2014). However, aside from this method being time consuming, the notion of being observed may pose a risk to alter one's HH behaviour (Boyce, 2008; Pickering et al., 2014). The use of microbial sampling to determine the effectiveness of HH after handwashing is often costly, and laboratory work may take a few days to process (Hautemanière et al., 2009). In recent years, the application of a fluorescent solution, which is luminescent under ultraviolet light, has become popular for indicating effective HH (Hautemanière et al., 2009; Higgins and Hannan, 2013; Turner et al., 1994). However, subjective visual inspection relies extensively on the training of examiners to interpret the images accurately (Hautemanière et al., 2009).

In 2012, an information technology tool called 'Hand-in-Scan' Semmelweis Hand Hygiene Scanner (HandInScan Kft, Debrecen, Hungary) was developed primarily for HH technique education and training (Fig. 1). This device appropriately indicated disinfected areas with 95.05% sensitivity and 98.01% specificity (Lehotsky et al., 2017). It is used with ultraviolet-marked ABHR that produces digital images of hand coverage. The quality of HH technique can be picked up in less than 1 min, and the generated report could provide objective visual feedback to users. The feedback indicates the percentages of ABHR coverage on hands and the regions missed during HH practice (Duong et al., 2017; Lehotsky et al., 2017).

Using visual aids in teaching stimulates interest and promotes understanding (Burgess, 1947). In a multicentre study conducted on 136 HCWs in Hungary, the rate of inadequate hand rubbing greatly reduced from 50% to 15% after introducing the use of 'Hand-in-Scan' in the clinical setting. However, as admitted by the authors, this study was limited due to the absence of a control group (Lehotsky et al., 2015).

Nursing students who exhibit patient safety practices, such as HH, will be in a better position to grasp the essence of vigilance and perform what is expected in the clinical setting (Gantt and Webb-Corbett, 2010). Traditional teaching methods are insufficient to instil teaching concepts and maintain long-lasting improvement in HH practices (Lehotsky et al., 2015). The use of electronic devices and computer applications in university teaching has become popular nowadays (Lehotsky et al., 2016). Therefore, a feasibility study was conducted to evaluate the effectiveness of integrating the 'Hand-in-Scan' device in HH teaching sessions for nurses under training. For hypothesis, the visual feedback generated by the device could reinforce the learners to pay more attention to the neglected regions, and in turn, enhance HH compliance.

2. Aims and objectives

This study aims to determine the feasibility of introducing the use of 'Hand-in-Scan' into existing nursing programmes in HH education. The specific objectives are:

- to evaluate the feasibility of the trial, indicated by the recruitment rate, compliance rate and students' satisfaction towards the use of 'Hand-in-Scan' as a learning activity;
- to determine the effectiveness of using the 'Hand-in-Scan' on the enhancement of HH technique.

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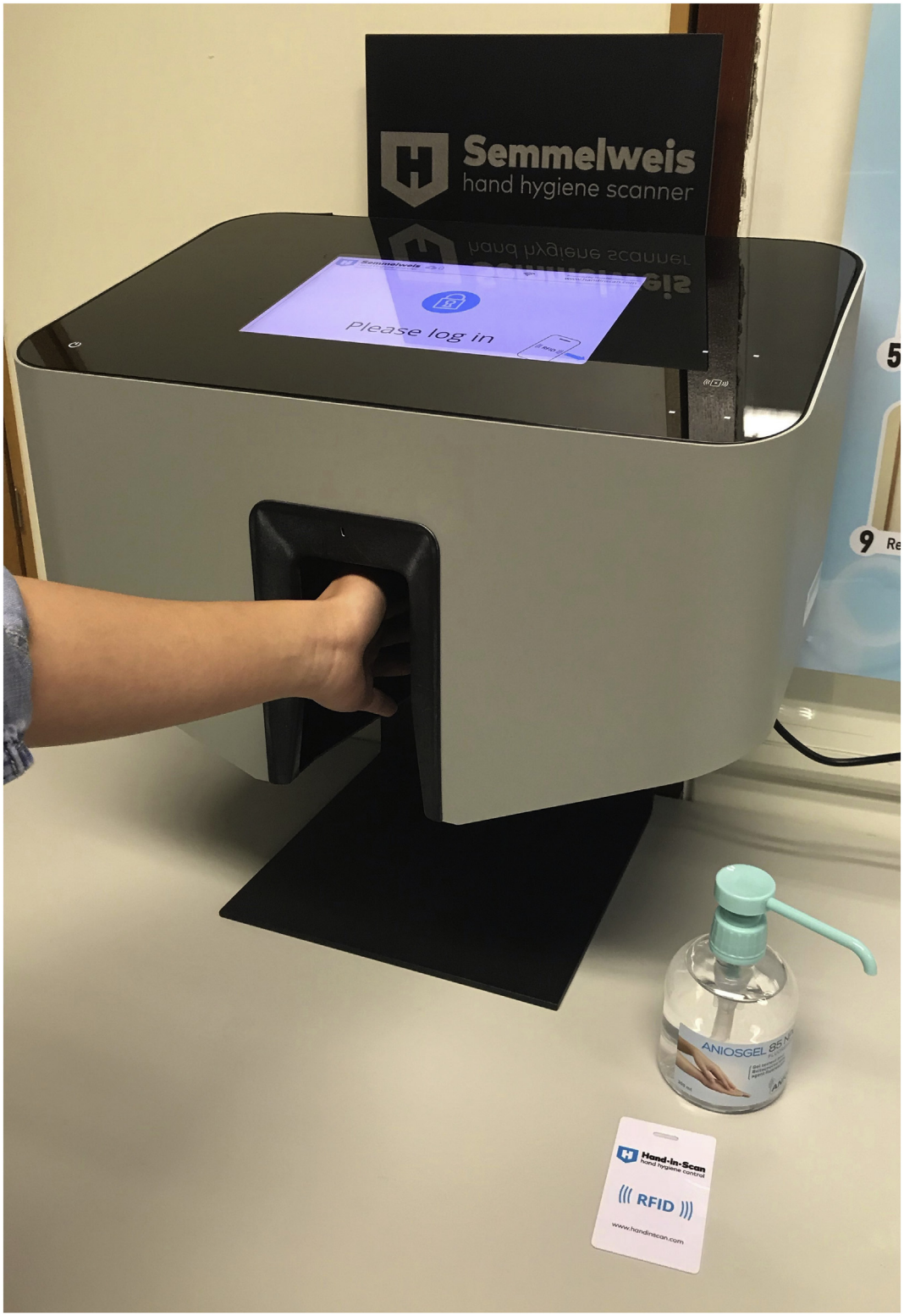


Fig. 1. 'Hand-in-Scan' Semmelweis Hand Hygiene Scanner.

3. Methods

3.1. Study design

A single-blinded quasi-experimental study, in which participants were blinded to the study hypothesis (i.e. the visual feedback from the scanner report may enhance HH compliance), was conducted. Although the assessors were not blinded to the grouping of the participants, minimum bias in the assessment occurred due to the objective measurement of the 'Hand-in-Scan'. Participation in the study was voluntary and would not affect the students' course grades of the respective subject. Written, informed consent was obtained from each participant, who could withdraw from the study anytime.

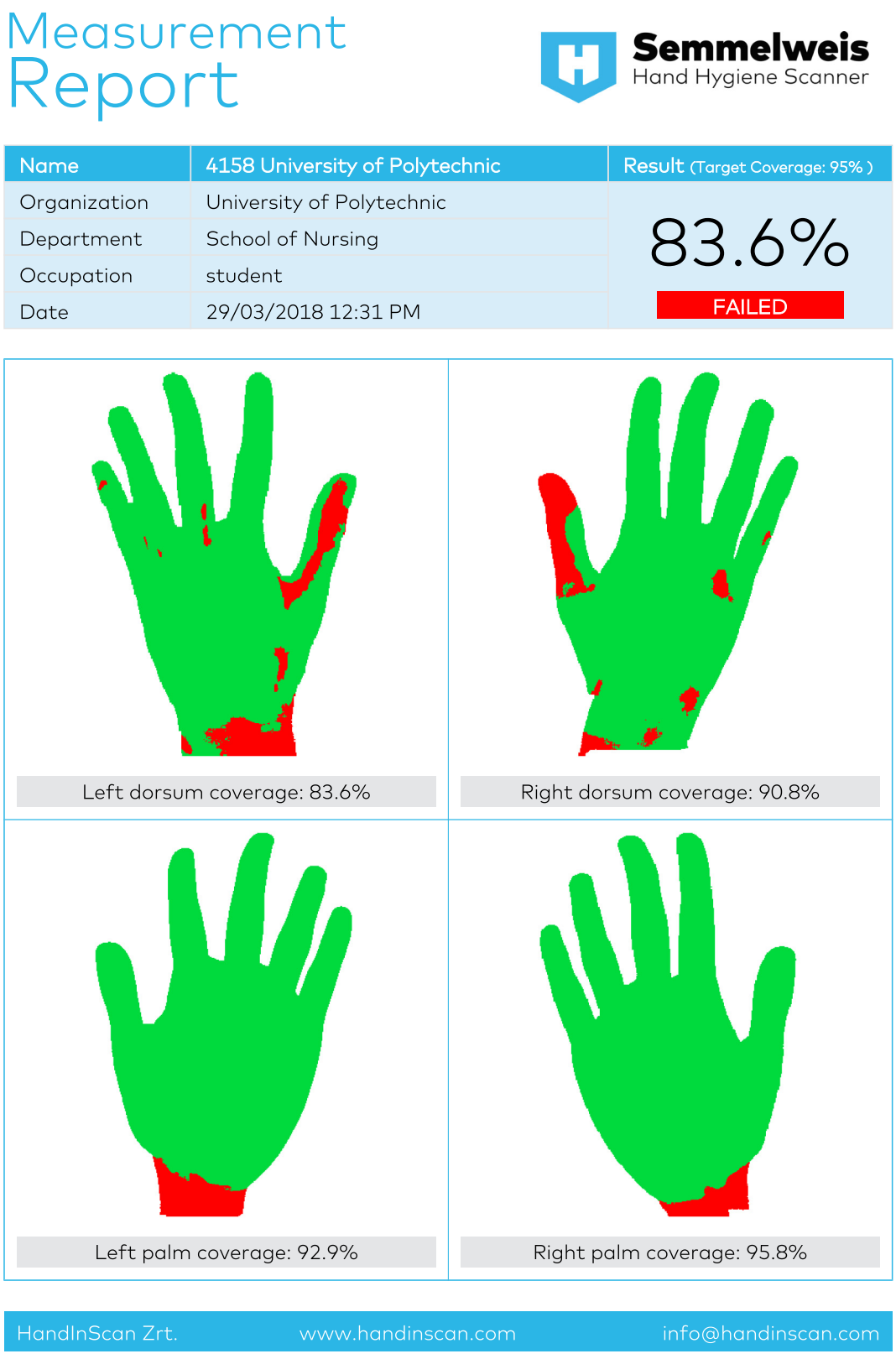


Fig. 2. Measurement report (sample). (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

3.2. Setting and participants

A convenience sample of two separate classes of first year undergraduate students from the general nursing ($n = 162$) and mental health nursing ($n = 70$) programmes were invited. Students with open wounds or lesions on hands, have a history of allergy to ABHR, or declined to participate were excluded. Students of both programmes are enrolled in the 'Public Health and Infection Control' subject (SN3303), in which a two-hour HH teaching session would be delivered. To prevent possible contamination of the intervention protocol among

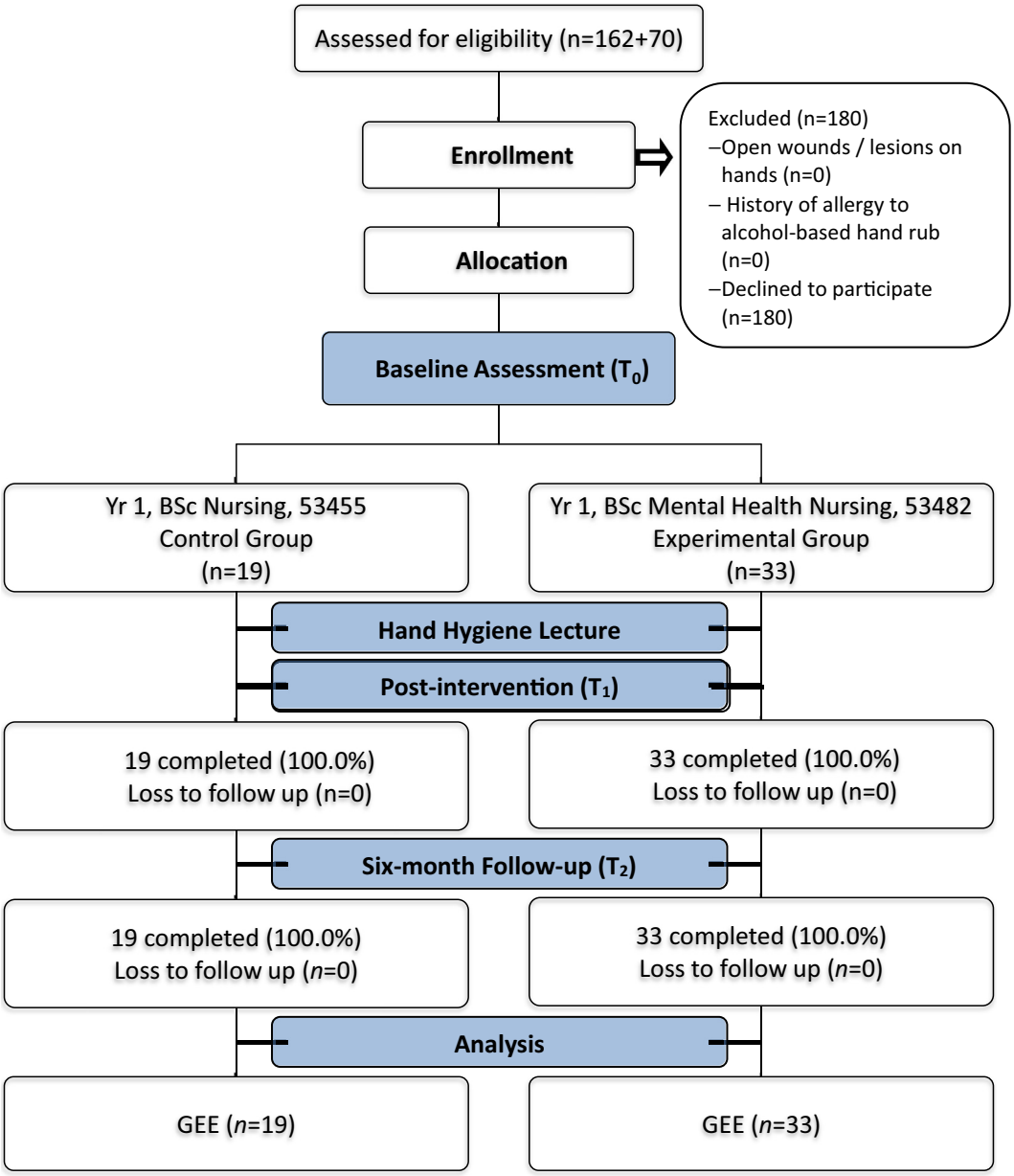


Fig. 3. Flow diagram of the participants.

participants, students of the same programme were assigned to either experimental or control groups to minimize discussion about the teaching approaches delivered.

3.3. Procedures

Potential subjects were recruited via a briefing session during the first week of the semester. Procedures were conducted at the 'Centre for Infection Control' under the School of Nursing of the University. Basic personal data of the recruited subjects, including gender, hand dominance and any prior exposure to HH training, were gathered. A total of 52 students were recruited, with 19 from the general nursing programme, and 33 from the mental health nursing programme. The former was assigned to the control group, and the latter to the experimental group, facilitating the evaluation of the effect of the 'Hand-in-Scan' as a learning tool.

Baseline performance of the HH practice (T0) was evaluated by the 'Hand-in-Scan'. Before scanning, the participants were asked to remove all jewellery, watches and bracelets. They were also required to wash their hands with soap and water to remove any sunscreen or photo-protective lotion. They were then instructed to perform HH following their usual technique of using hydroalcoholic gel that contains a fluorescent agent (Aniosgel 85 NPC Fluorescent, Laboratories Anios). The participants were instructed to use adequate gel to cover the hands, usually by squeezing one pump (3 mL) of the gel for hand disinfection. The hands were rubbed until the gel was completely dried. Thereafter, the participant placed their hands one by one into the 'Hand-in-Scan' (Model: HINST20E3WS0P01), which could capture the image of the hands in seconds. After placing the hand into the device, the screen shows the position of the hand for the user to know how to position his/her hand for a better image to be captured. A radiofrequency identification card with a corresponding code was used to identify each participant and to ensure their anonymity.

After the baseline assessment of HH practice, participants of both programmes received theoretical input on proper HH. A two-hour lecture on HH was delivered by the same staff, who has ample experience in teaching this topic. The teaching session highlighted the basic principles of HH, the 'Five Moments' for HH practice in healthcare settings

Table 1
Homogeneity test of characteristics between the two groups (n = 52).

	All (n = 52)	BSc MH (experimental group) (n = 33)	BScN (control group) (n = 19)	p-Value
	n (%)	n (%)	n (%)	
Gender				
Male	15 (28.8%)	11 (33.3%)	4 (21.1%)	> 0.05[a]
Female	37 (71.2%)	22 (66.7%)	15 (28.9%)	
Exposure to hand hygiene interventions				
Yes	44 (84.6%)	29 (87.9%)	15 (78.9%)	> 0.05[a]
No	8 (15.4%)	4 (12.1%)	4 (21.1%)	
Dominant hand				
Right	50 (96.2%)	31 (93.9%)	19 (100.0%)	> 0.05[a]
Left	2 (38.5%)	2 (6.1%)	0 (0.0%)	
Regions of hands missed				
Palms				
Missed	5 (9.6%)	4 (12.1%)	1 (5.3%)	> 0.05[a]
Covered	47 (90.4%)	29 (87.9%)	18 (94.7%)	
Back of hands				
Missed	24 (46.2%)	19 (57.6%)	5 (26.3%)	< 0.05[b]
Covered	28 (53.8%)	14 (42.4%)	14 (73.7)	
Finger webs				
Missed	12 (23.1%)	8 (24.2%)	4 (21.1%)	> 0.05[a]
Covered	40 (76.9%)	25 (75.8%)	15 (78.9%)	
Back of fingers				
Missed	17 (32.7%)	12 (36.4%)	5 (26.3%)	> 0.05[b]
Covered	35 (67.3%)	21 (63.6%)	14 (73.7%)	
Thumbs				
Missed	38 (73.1%)	25 (75.8%)	13 (68.4%)	> 0.05[b]
Covered	14 (26.9%)	8 (24.2%)	6 (31.6%)	
Finger tips				
Missed	4 (7.7%)	4 (12.1%)	0 (0.0%)	> 0.05[a]
Covered	48 (92.3%)	29 (87.9%)	19 (100.0%)	
Wrists				
Missed	49 (94.2%)	33 (100.0%)	16 (84.2%)	< 0.05*[,a]
Covered	3 (5.8%)	0 (0.0%)	3 (15.8%)	

	All (n = 52)	BScMH (experimental group) (n = 33)	BScN (control group) (n = 19)	p-Value
	M ± SD	M ± SD	M ± SD	
Overall hand coverage (%)	86.05 ± 14.15	84.19 ± 15.24	89.28 ± 11.69	> 0.05[c]
Palm & dorsum (left) (%)	89.05 ± 11.16	87.36 ± 11.50	91.97 ± 10.18	> 0.05[c]
Palm & dorsum (right) (%)	89.08 ± 14.12	87.44 ± 15.00	91.94 ± 12.30	> 0.05[c]
Palm (right & left) (%)	94.26 ± 5.34	94.05 ± 4.83	94.63 ± 6.24	> 0.05[c]
Dorsum (right & left) (%)	86.68 ± 14.56	84.15 ± 15.55	90.94 ± 11.91	< 0.05*[,c]

Abbreviation: M, Mean; SD, Standard deviation; BScMH, Bachelor of Science in Mental Health Nursing; BScN, Bachelor of Science in Nursing.
[a] Fisher's exact test for categorical data.
[b] Chi-square test for categorical data.
[c] Mann-Whitney U test for continuous data.
* Statistically significant at $p < 0.05$.

(WHO, 2009) and the seven regions of the hands should be covered during hand rubbing. These hand regions include the palms, back of hands, finger webs, back of fingers, thumbs, finger tips and wrists (Centre for Health Protection, 2017).

After the teaching session, HH compliance of both groups was evaluated using the 'Hand-in-Scan' (T1). Before the assessment (T1), the baseline report (T0) was shown to each participant in the experimental group, and visual feedback was provided via a measurement report about the neglected hand regions in their assessment. Individual report included the overall surface coverage of ABHR and coverage of the palm and dorsal regions on both hands. A sample of the measurement report is displayed in Fig. 2. To determine the sustained learning effect of the participants, repeated evaluation of the HH performance was conducted six months after intervention (T2). Conversely, the measurement report was not shown to the participants in the control group until they have received the HH assessment at T2.

3.4. Outcome measurements

HH performance was evaluated in terms of overall surface coverage of ABHR and coverage of the palm and dorsal regions of both hands. In evaluating the coverage of ABHR on the dorsum or the palm, the lower percentage was considered as the reading. For example, if the dorsum coverage is 84% and 82% on the left and right hands respectively, 82%

Table 2
Hand coverage (%) by alcohol-based handrub between groups at different timepoints by GEE analysis.

	BScMH (experimental group) (n = 33)	BScN (control group) (n = 19)	Comparisons between groups	
	EM ± SE	EM ± SE	β (95% CI)	p-Value
Overall hand coverage (%)				
T0	84.19 ± 2.61	89.28 ± 2.61		
T1	95.79 ± 1.16	90.98 ± 2.80	9.90 (0.97, 18.83)	0.030*
T2	94.05 ± 1.24	92.17 ± 3.09	6.97 (−0.79, 14.73)	0.078
Palm & dorsum (left) (%)				
T0	87.36 ± 1.97	91.97 ± 2.27		
T1	97.49 ± 0.70	93.30 ± 1.96	8.80 (1.52, 16.08)	0.018*
T2	96.08 ± 1.03	96.60 ± 0.86	4.09 (−2.20, 10.38)	0.203
Palm & dorsum (right) (%)				
T0	87.44 ± 2.57	91.94 ± 2.75		
T1	96.73 ± 1.13	93.42 ± 2.54	7.81 (−0.59, 16.20)	0.069
T2	95.02 ± 1.28	92.79 ± 3.11	6.73 (−0.89, 14.35)	0.083
Palm (right & left) (%)				
T0	94.05 ± 0.83	94.63 ± 1.39		
T1	98.31 ± 0.36	97.21 ± 0.75	1.69 (−1.82, 5.21)	0.345
T2	96.41 ± 0.57	95.77 ± 1.20	1.22 (−2.80, 5.24)	0.551
Dorsum (right & left) (%)				
T0	84.14 ± 2.70	90.94 ± 2.66		
T1	96.00 ± 1.22	91.95 ± 2.86	10.85 (1.48, 20.21)	0.023*
T2	96.17 ± 1.28	93.07 ± 3.13	9.90 (2.16, 17.63)	0.012*

Abbreviation: EM, Estimated mean; SE, Standard error; 95% CI, 95% Confidence Interval; GEE, Generalized estimating equations; BScMH, Bachelor of Science in Mental Health Nursing; BScN, Bachelor of Science in Nursing.
Timepoints: T0, Baseline; T1, Post-intervention; T2, 6 months post-intervention.
* Statistically significant at $p < 0.05$.

was considered for analyses. This default principle was also applied when the overall coverage (%) was determined by the device.

In addition, the missing regions on the hands without ABHR coverage could be identified in the report, with areas covered by ABHR displayed in green and missed areas in red. As per factory default, HH performance was classified as 'pass' only if the surface coverage attained 95% or above in all four sides of the hands (i.e. right dorsum, left dorsum, right palm, left palm). As explained by the manufacturer, this stringent 'Passed/Failed' concept assumed that a high risk of contamination still exists even when three sides of the hands are perfect, with one side missing substantial areas (Fig. 2) ('Hand-in-Scan' User Manual, 2016).

The satisfaction of the participants towards the use of the 'Hand-in-Scan' was evaluated after measurements were obtained at T2. The five-item questionnaire was adapted from the satisfaction subscale of the 'National League for Nursing Student Satisfaction and Self-Confidence in Learning Scale', which has a Cronbach's alpha of 0.94 (Jeffries and Rizzolo, 2006). These items include the following: (1) The use of hand scanner for teaching HH was helpful and effective; (2) Teaching HH with the hand scanner promoted my understanding of the concepts of HH; (3) I enjoyed how my instructor taught HH using the hand scanner; (4) The hand scanner used for teaching HH was motivating and helped me to learn; and (5) The way my instructor taught HH using the hand scanner was suitable to the way I learn. A five-point Likert-type response scale (1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; and 5 = Strongly Agree) was used, with a summative score ranging from 5 to 25. The higher the score, the higher the satisfaction towards the use of the 'Hand-in-Scan' as a learning tool. A comment box was also provided for participants to gather any narrative feedback on the trial.

3.5. Data analyses

Descriptive statistics for demographics and baseline hand coverage using ABHR of the students were presented. The estimated mean and standard error of the outcome variables of each timepoint (baseline, post-intervention and six months post-intervention) were computed. The association between categorical variables was examined using x^2 test or Fisher's exact test, where appropriate. The Mann-Whitney was used to determine group differences (group and gender differences) on hand coverage. Wilcoxon signed ranks test was used to detect differences before and after intervention for each gender.

Primary analysis was conducted using a generalized estimating equation (GEE) model with an autoregression correlation structure for the examination of the interactions among the groups over time (baseline, post-intervention and six months postintervention) in terms of hand coverage using ABHR or pass/fail of HH performance. Data that were assumed to be missed randomly were addressed using the GEE model (Bell et al., 2018). SPSS version 25.0 (IBM Corporation, USA) was used for all statistical analyses. All statistical tests were two sided, with a significance level set to 0.05.

4. Results

Data were collected from January to September 2018. A total of 52 students participated in the study. The overall recruitment rate was 22.4%. Compliance to the intervention protocol was high, with all participants completing the HH assessments at three timepoints (T0, T1 and T2). The flow diagram of the participants of this trial is illustrated in Fig. 3.

4.1. Baseline characteristics of the participants

All the recruited students, which comprised 71.2% (n = 37) females, and 28.2% (n = 15) males, were in their first year of study. Majority of them were right handed (96.2%, n = 50) and have received no prior HH training (84.6%, n = 44). The two groups were essentially comparable in hand coverage using ABHR. The most frequently neglected regions of the hands during hand rubbing were the wrists (94.2%), followed by the thumbs (73.1%), back of hands (46.2%), back of fingers (32.7%), finger webs (23.1%), palms (9.6%) and finger tips (7.7%). The overall hand coverage (%) by ABHR was 86.05 ± 14.15.

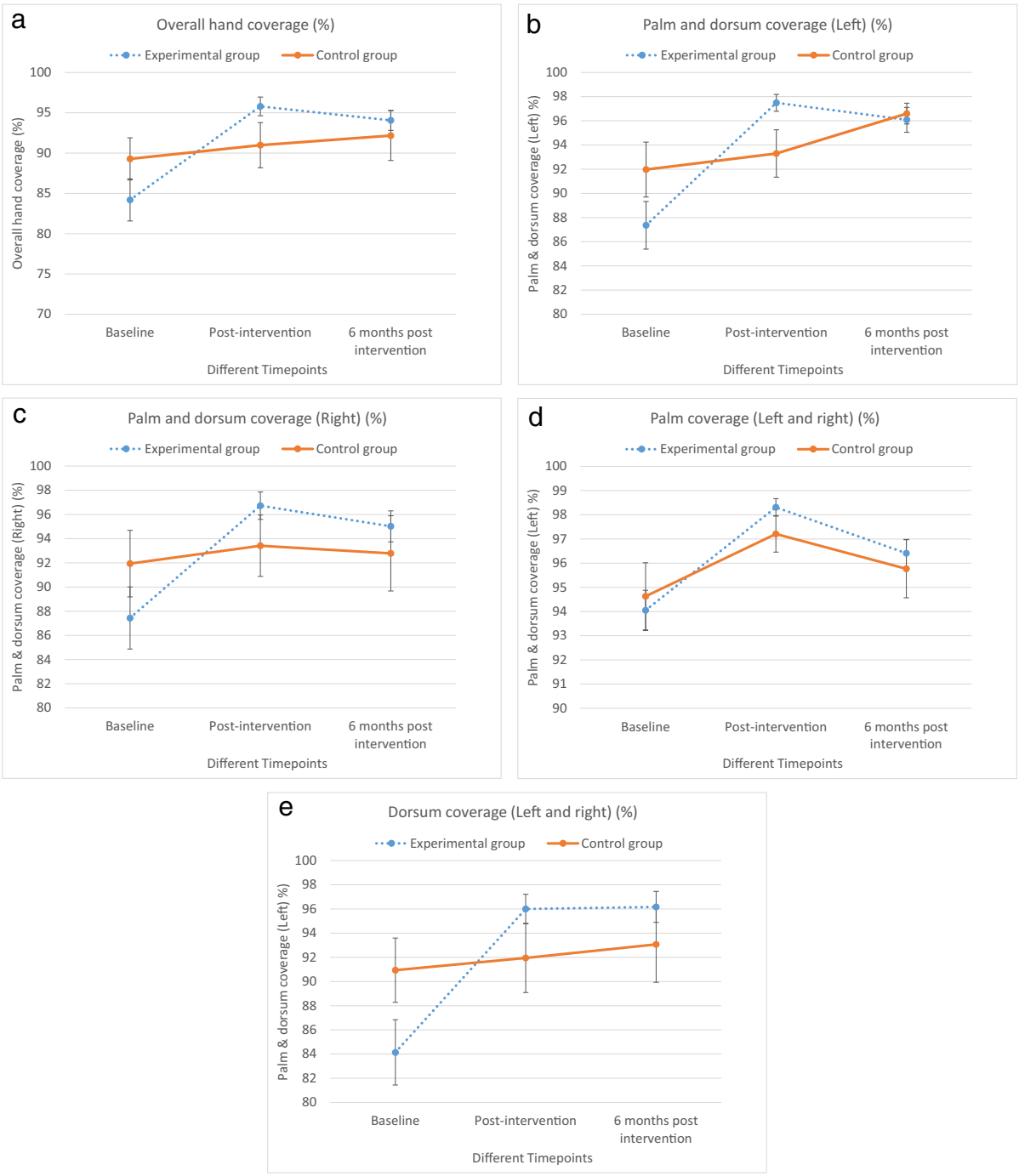


Fig. 4. Hand coverage (%) by ABHR between groups at different timepoints (panel a to panel e).

Even though no statistically significant differences were observed in majority of the baseline characteristics and HH performance between the groups, the control group generally had better hand coverage than those in the experimental group (Table 1).

4.2. Hand coverage (%) via ABHR at different timepoints

The difference of the two groups in terms of hand coverage by ABHR across different timepoints was compared via GEE model analysis. Significant improvements in HH performance in terms of overall hand coverage ($p < 0.05$) and left hand (palm and dorsum) ($p < 0.05$) after the intervention were observed in the experimental group. Sustained effect on HH performance in the dorsal region of both hands was observed even at T2 ($p < 0.05$) (Table 2). (Fig. 4a to e).

4.3. HH performance assessment by hand regions at different timepoints

The number of subjects who obtained a 'pass' in the HH performance by regions of hands was assessed. To attain a 'pass', hand surface coverage by ABHR should be 95% or above. A significant number of students obtained a 'pass' in terms of overall hand coverage (OR = 11.39, $p < 0.01$), left hand (OR = 5.40, $p < 0.05$), right hand (OR = 22.37, $p < 0.001$), palm (OR = 8.22, $p < 0.05$) and dorsum (OR = 5.59, $p < 0.05$) coverage at T1. Sustained effect on HH performance was observed even at T2 in several hand regions (overall, right hand and dorsum of hands) (Table 3). In addition, participants in

Table 3
Hand hygiene performance by regions of hands between groups at different timepoints by GEE analysis.

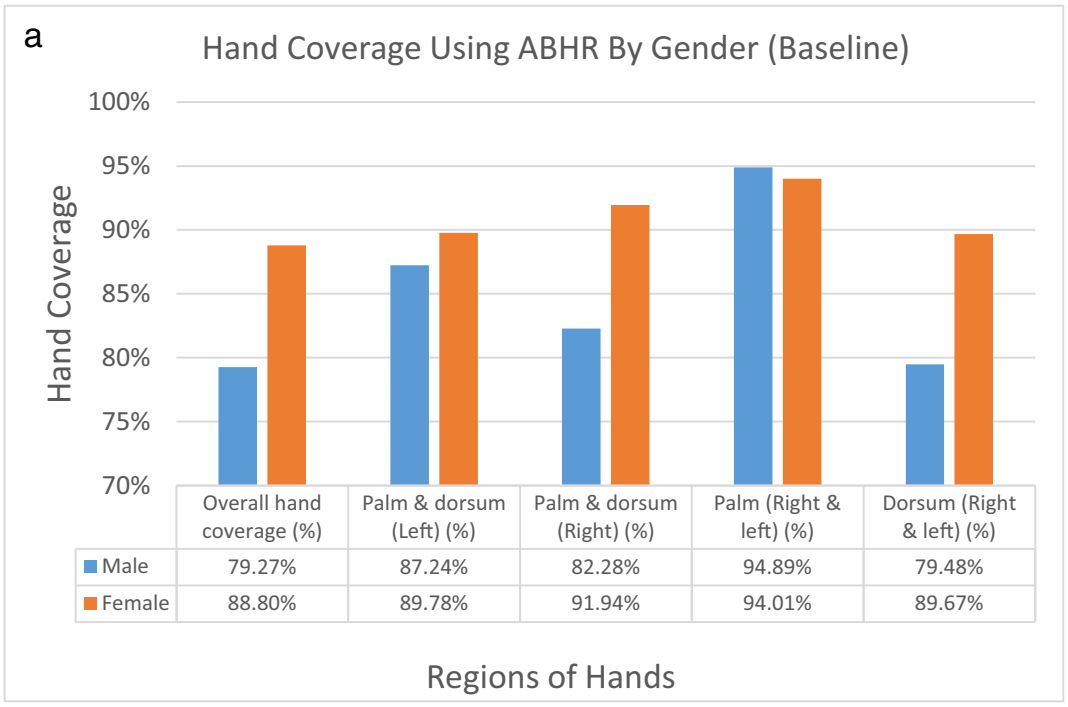
	BScMH (experimental group) (n = 33)	BScN (control group) (n = 19)	Wald chi-square	OR	95% CI	p-Value
	n (%)[a]	n (%)[a]				
Overall hand coverage						
T0	6 (18.2%)	9 (47.4%)				
T1	25 (75.8%)	10 (52.6%)	8.84	11.39	2.29, 56.64	0.003**
T2	20 (60.6%)	10 (52.6%)	5.22	5.61	1.28, 24.62	0.022*
Left hand						
T0	9 (27.3%)	10 (52.6%)				
T1	25 (75.8%)	12 (63.2%)	4.21	5.40	1.08, 27.04	0.040*
T2	25 (75.8%)	13 (68.4%)	3.04	4.27	0.83, 21.89	0.061
Right hand						
T0	11 (33.3%)	12 (63.2%)				
T1	29 (87.9%)	10 (52.6%)	12.31	22.37	3.94, 127.00	0.000***
T2	23 (69.70%)	11 (57.9%)	5.78	5.74	1.38, 23.82	0.016*
Palms						
T0	16 (48.5%)	13 (68.4%)				
T1	30 (90.9%)	14 (73.7%)	4.27	8.22	1.12, 60.63	0.039*
T2	25 (75.8%)	12 (63.2%)	3.08	4.20	0.81, 21.73	0.087
Dorsum of hands						
T0	8	10				
T1	24	12	4.34	5.59	1.11, 28.19	0.037*
T2	24	12	5.05	5.14	1.23, 21.41	0.025*

Abbreviation: OR, Odds ratio (the control group was the referent); 95% CI, 95% Confidence Interval; GEE, Generalized estimating equations; BScMH, Bachelor of Science in Mental Health Nursing; BScN, Bachelor of Science in Nursing.
Timepoints: T0, Baseline; T1, Post-intervention; T2, 6 months post-intervention.
[a] Number of pass (percentage), [NB: To achieve a pass, the hand surface coverage by alcohol-based handrub should attain 95% or above in all 4 sides of hands].
* Statistically significant at $p < 0.05$.
** Statistically significant at $p < 0.01$.
*** Statistically significant at $p < 0.001$.

Table 4
Hand coverage using alcohol-based handrub by gender.

	Male (n = 15)	Female (n = 37)	Between group comparison
	M ± SD	M ± SD	p-Value[a]
Before intervention			
Overall hand coverage (%)	79.27 ± 19.76	88.80 ± 10.23	> 0.05
Palm & dorsum (left) (%)	87.24 ± 13.40	89.78 ± 10.23	> 0.05
Palm & dorsum (right) (%)	82.28 ± 10.78	91.94 ± 10.16	> 0.05
Palm (right & left) (%)	94.89 ± 5.36	94.01 ± 5.38	> 0.05
Dorsum (right & left) (%)	79.48 ± 19.97	89.67 ± 10.58	> 0.05
After intervention			
Overall hand coverage (%)	91.32 ± 13.08	95.13 ± 7.50	> 0.05
Palm & dorsum (left) (%)	95.52 ± 6.51	96.14 ± 6.50	> 0.05
Palm & dorsum (right) (%)	92.79 ± 13.34	96.62 ± 5.80	> 0.05
Palm (right & left) (%)	97.11 ± 3.22	98.24 ± 2.37	> 0.05
Dorsum (right & left) (%)	91.83 ± 13.70	95.60 ± 7.66	> 0.05
Within group comparison p-Value[b]			
Overall hand coverage (%)	< 0.05*	< 0.01**	–
Palm & dorsum (left) (%)	< 0.01**	< 0.01**	–
Palm & dorsum (right) (%)	< 0.05*	< 0.01**	–
Palm (right & left) (%)	< 0.05*	< 0.001***	–
Dorsum (right & left) (%)	< 0.05*	< 0.01**	–

Abbreviation: M, Mean; SD, Standard deviation.
[a] Mann-Whitney U test.
[b] Wilcoxon signed ranks test.
* Statistically significant at p < 0.05.
** Statistically significant at p < 0.01.
*** Statistically significant at p < 0.001.



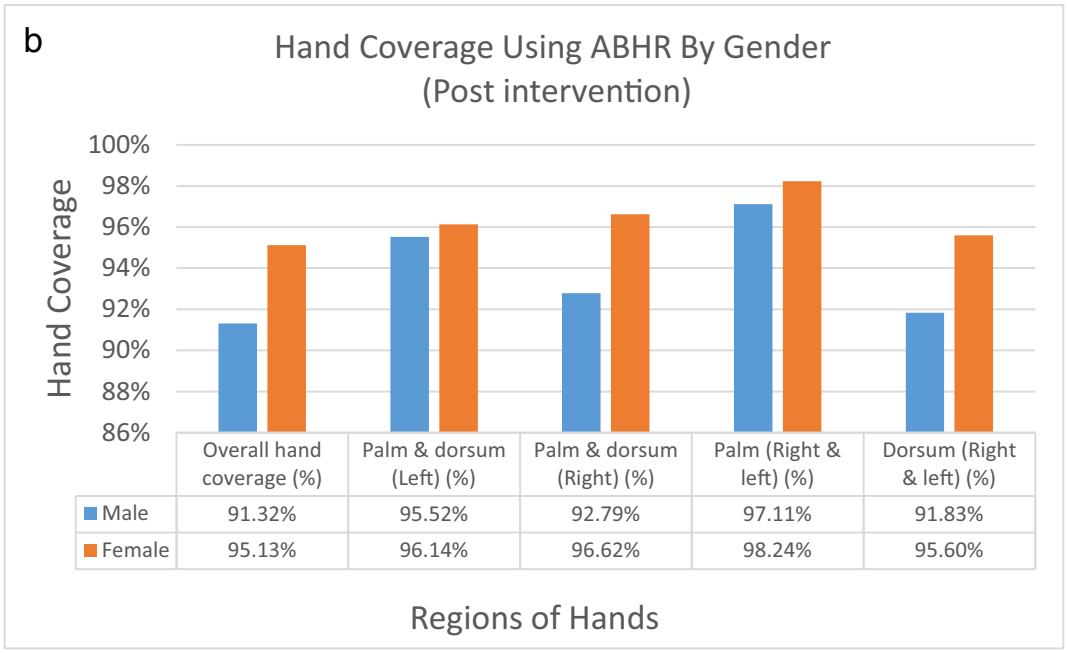


Fig. 5. Hand coverage using ABHR by gender (panel a to panel b).

the experimental group had a significant reduction in neglecting the wrists during hand rubbing compared with the control group ($p < 0.05$).

4.4. Hand coverage using ABHR by gender

Subgroup analyses of hand coverage using ABHR in consideration of gender indicated that female students generally performed better than male students, even though the group differences were not statistically significant before or after the intervention. Nevertheless, within-group comparison indicated statistically significant improvement in hand-rubbing performance before and after intervention in both genders (Table 4) (Fig. 5a to b).

4.5. Compliance and satisfaction towards the teaching approach using 'Hand-in-Scan'

Compliance to the protocol and all follow-up measurements were high (100%) (Fig. 3). In general, the participants had high satisfaction towards the use of the hand scanner as a learning device in HH teaching, reflected by an overall satisfaction rate of over 85%. No statistically significant difference in the satisfaction towards this teaching approach between groups was noted (Table 5). Only one student provided some narrative feedback on the questionnaire and suggested for the hand scanner to be considered for open booking for students' practice and self-evaluation. This respondent welcomed the idea of integrating this device into the HH teaching session and suggested that

Table 5
Results of the 'Students' Satisfaction Survey' after the intervention.

	All (n = 52)	BSc mental (experimental group) (n = 33)	BScN (control group) (n = 19)	p-Value[a]
	M ± SD	M ± SD	M ± SD	
	Mean (SD)			
Q1. The use of hand scanner in teaching hand hygiene was helpful and effective	4.33 ± 0.51	4.30 ± 0.47	4.37 ± 0.60	> 0.05
Q2. Teaching hand hygiene with the hand scanner provided me with a variety of learning materials and activities to promote my learning the hand hygiene curriculum	4.13 ± 0.60	4.09 ± 0.58	4.21 ± 0.63	> 0.05
Q3. I enjoyed how my instructor taught hand hygiene using the hand scanner	4.29 ± 0.75	4.24 ± 0.71	4.37 ± 0.83	> 0.05
Q4. The hand scanner used in teaching hand hygiene was motivating and helped me to learn	4.27 ± 0.69	4.33 ± 0.69	4.16 ± 0.69	> 0.05
Q5. The way my instructor taught hand hygiene using the hand scanner was suitable to the way I learn	4.37 ± 0.66	4.30 ± 0.64_	4.47 ± 0.70	> 0.05
Overall satisfaction scores	21.38 ± 2.58	21.27 ± 2.43	21.58 ± 2.89	> 0.05
Overall satisfaction (%)	85.54 ± 10.33	85.09 ± 9.71	86.32 ± 11.57	> 0.05

Abbreviation: M, Mean; SD, Standard deviation.
Q1 to Q5: 1 to 5, the higher the satisfaction of the students towards the use of "Hand-in-Scan".
Overall satisfaction scores: 5–25, the higher the satisfaction of the students.
[a] Mann-Whitney U test.

specific assessment weighting should be assigned to this laboratory skill.

5. Discussion

Using a hand scanner to introduce 'Hand-in-Scan' into existing nursing programmes in HH education was found to be feasible. The recruitment rate in this study was relatively low due to the voluntary nature of participation. Nevertheless, once a student agreed to participate in the study, the compliance rate was high, as indicated by their full commitment without dropouts. The overall satisfaction of participants towards the use of the hand scanner was high, reflecting that integrating modern technology in nursing education is widely accepted by students. Unexpectedly, no statistically significant difference was observed between groups in terms of satisfaction towards this device, probably because students were successfully blinded from the study hypothesis and were solely impressed by the advanced teaching technology. Therefore, the individual measurement reports of the hand scanner could be considered as an objective indicator over the subjective perception of the participants to determine group differences.

Baseline assessment of HH performance showed that the most frequently neglected hand regions during hand rubbing were the wrists, followed by the thumbs, dorsum of hands, finger webs, palms and finger tips. Previous literature has also reported that the wrists, thumbs and dorsum of hands were frequently missed during hand rubbing (Arias et al., 2016; Škodová et al., 2015; Szilágyi et al., 2013). However, the finger tips were also a frequently missed region during hand disinfection with the lowest compliance rates (Arias et al., 2016; Duong et al., 2017); however, the case in our participants was different. Even though fingertip coverage was high, no information was obtained whether the nails were covered by the ABHR because of the limited function of the hand scanner. To ensure thorough disinfection of the finger tips, a fingertip scrub (i.e. rotational rubbing of the finger tips in opposite palms) was recommended (Galluzzi et al., 2014). Pires et al. (2017) also demonstrated in their trial that a modified WHO six-step technique called 'Fingertips First' showed greater efficacy than the traditional WHO six-step technique in reducing fingertip contamination.

Significant improvement in the HH performance in terms of overall hand coverage at different hand regions after intervention was observed in the experimental group. This result indicates that the visual feedback of the hand scanner had a positive impact in improving the HH technique quality of students and in increasing their alertness to previously neglected hand regions during hand rubbing. The hand scanner could be considered as an efficient tool in driving behavioural change in HH performance. Proper education and training for improving and maintaining good HH practices remain a priority. Regular assessment using this device with an immediate feedback strategy and adopting it as a mandatory teaching approach is proposed.

Participants in the experimental group demonstrated a significant improvement in wrist disinfection during hand rubbing compared with those in the control group, which could be due to the fact that the HH teaching session included wrist disinfection. Whether to include the wrist as a step for hand disinfection varies among different international organizations. The WHO six-step technique (WHO, p. 163) and the three-step technique published by the Center for Disease Control and Prevention (CDC, 2002, p. 32) emphasized on regions, such as palms, finger webs, thumbs and dorsum of hands; whereas some organizations (Centre for Health Protection, Hong Kong [CHP]; National Health Services, England [NHS]; National Clinical Guideline Centre [NCGC], 2012) also included rubbing each wrist with the opposite hand in their guidelines. Although current practice involves the wrists as part of hand decontamination, evidence is still inadequate to prove that washing the wrists or rolling up the sleeves during care delivery is better than not doing so. However, working clothes should not deter effective hand disinfection under any circumstances (NCGC Clinical Guideline, 2012).

Subgroup analyses of hand coverage indicate that the female students generally performed better than the male students. This finding is consistent with many previous studies, in which females performed significantly better than males in terms of rubbing quality and surface coverage (Lehotsky et al., 2016; Szilágyi et al., 2013; Škodová et al., 2015). Educators could consider gender differences on HH performance when teaching this common but important procedure.

6. Limitations and recommendations

Given the small number of participants enrolled in this feasibility study, generalization of results is limited. Future trials involving a larger sample size should be conducted to inform decisions on the routine use of a hand scanner in nursing education. Studies of a wider scale could also include the monitoring of the 'Five Moments of Hand Hygiene' recommended by the WHO, recording the duration of hand rubbing, hand size and amount of sanitizer use and comparing the HH performance of students with other cohorts when the hand scanner is used. Even though the Hawthorne effect can possibly affect HH performance, such bias was minimum, because this effect may occur in both groups of students, and the research personnel who assisted the

participants the during hand scanning procedure was not involved in the teaching and grading of the subject.

7. Conclusion

Preliminary findings indicate that the visual feedback of the hand scanner has a positive impact in improving the HH technique quality of students and in increasing their alertness to previously neglected hand regions during hand rubbing. Future trials of a wider scale should be conducted to inform decisions on the routine use of a hand scanner in nursing education.

Conflicts of interest

None.

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