Title: Simulation education as a single intervention does not improve hand hygiene practices – a randomized controlled follow-up study

Corresponding author: Miia M. Jansson

Ph.D.

Email: miia.jansson@oulu.fi

Tel: +358 44 592 59 48

Division of Intensive Care, Department of Anesthesiology, Oulu University Hospital, Oulu, Finland

Unit of Nursing Science and Health Management, University of Oulu, Finland

Medical Research Center Oulu, Oulu, Finland

Address: Department of Anesthesiology, Oulu University Hospital, P.O. Box 26, FIN-90029, OYS, Oulu, Finland

Hannu P. Syrjälä

Adjunct professor

Department of Infection Control, Oulu University Hospital, Oulu, Finland

Medical Research Center Oulu, Oulu, Finland

Pasi P. Ohtonen

MSc. (Statistics)

Department of Anesthesiology, Oulu University Hospital, Oulu, Finland

Merja H. Meriläinen

Ph.D.

Division of Intensive Care, Department of Anesthesiology, Oulu University Hospital, Oulu, Finland

Medical Research Center Oulu, Oulu, Finland

Helvi A. Kyngäs

Professor

Unit of Nursing Science and Health Management, University of Oulu, Finland

Part-time Chief Nursing Officer, Northern Ostrobothnia Hospital District

Medical Research Center Oulu, Oulu, Finland

Tero I. Ala-Kokko

Professor

Division of Intensive Care, Department of Anesthesiology, Oulu University Hospital, Oulu, Finland

Medical Research Center Oulu, Oulu, Finland

Conflict of interest

No conflict of interest has been declared by the authors.

Author contributions

M.M.J., H.P.S., P.P.O., M.H.M., H.A.K., and T.I.A.-K. contributed to the study design. M.M.J. contributed to data collection. M.M.J. and P.P.O. performed the data analysis. M.M.J., H.P.S., P.P.O., M.H.M., H.A.K., and T.I.A.-K. contributed to data interpretation and manuscript preparation.

Acknowledgements

The authors thank SimLab personnel from Oulu University of Applied Science and study nurse, Sinikka Sälkiö, for their valuable help during data collection. In addition, all of the critical care nurses who participated in this study are respectfully acknowledged.

BACKGROUND

Healthcare-associated infections (HAIs) are a continuing problem in intensive and critical care, which remain a leading cause of morbidity, mortality, [1–3] and excessive length of stay leading to high healthcare costs. [3] In developed countries, HAIs concerns 9–37% of those patients admitted to intensive care units (ICUs). Although ICUs account for a relatively small proportion of hospitalized patients, infections acquired in these units accounted for >20% of all HAIs. [4]

According to different estimates, approximately 55–70% of cases of catheter-associated bloodstream infections (CRBIs) and catheter-associated urinary tract infections and 55% of cases of ventilator-associated pneumonia and surgical site infections could be preventable through intensive infection control programs. [3] Despite previous educational intervention studies, [5–8] most of the effects have remained small to moderate and have often been short-term. [9]

Proper hand hygiene (HH) has been cited as the single most effective measure for preventing HAIs. [10–11] However, critical care nurses' adherence to HH guidelines has ranged from a low of 6% to a high of 65%, [5–6, 12–16] while the self-reported adherence has ranged from 59% to 92%. [14, 16–18] In addition, critical care nurses' awareness of HH guidelines has been limited. [17, 19]

In the recent years, advanced, high-fidelity teaching methods that require the participants to behave as they would in real life have been associated with improved learning (e.g., cognitive, behavior and psychomotor skills) [20–21] and clinical outcomes (e.g., fewer placement failures, arterial punctures, needle passes, and pneumothoraxes, decreased incidence of CRBIs).[22–24] Accordingly training via simulation could also provide an ideal learning environment with hands-on experience while promoting HH behavior. However, the effectiveness of simulation education with verbal feedback in improving infection control practices on nursing continuing education is still uncertain due to the lack of published studies and robust evidence. [25]

In this study, we aimed to evaluate how critical care nurses' knowledge of and adherence to current HH guidelines differ between randomly allocated intervention and control groups before and after simulation education in both the simulation setting and clinical practice. The hypothesis was that in the intervention group, knowledge of and adherence to current HH guidelines might increase compared with a control group after simulation education.

MATERIAL AND METHODS

Study design

A longitudinal, single-center, parallel, randomized controlled trial (RCT) with repeated measurements was conducted in a single academic center in a 22-bed adult mixed medical-surgical ICU in Finland from February 2012 to March 2014.

Sample and ethical considerations

The study population, eligibility criteria for participants, sample size, type of randomization, random allocation and recruitments have been described elsewhere. [21] Due to the nature of the intervention, a blinded experiment was not possible. However, the research assistant and biostatistician who collected the data and assessed the outcomes were blinded to group assignment. According to the Medical Research Act (488/1999 and amendments 295/2004), approval of the local ethics committee was not required for studies focusing on health care workers (HCWs). However, the study protocol was approved by the relevant academic center in fall 2011 and 2013. In addition, written informed consent from participants was obtained prior to inclusion in the study (Declaration of Helsinki 2013).

Intervention and study protocol

Each simulation session was carried out via four phases: 1) An orientation to the simulation center (SimLab, Oulu University of Applied Science, Oulu, Finland) and high-fidelity simulation setting, 2) an orientation to mannequin (HAL, Gaumard, Miami, FL) capabilities, and 3) actual simulated scenario. Finally, 4) only the intervention group participated in a post scenario debriefing session, and received verbal feedback. A structured, 60-minute debriefing took place in small groups (n = 8) and was carried out by two independent educators who specialized in simulation pedagogy and key areas (e.g., indications for HH, the duration of handrubbing, HH technique, and other aspects of HH listed in Table 1). All groups received the same amount of educational input concerning current HH guidelines [11] and the role of HH in reducing cases of ventilator-associated pneumonia. [26]

The baseline (initially before the intervention) and initial post-intervention (3 months after the intervention) measurements were conducted in the high-fidelity simulation setting (follow-up I). The final post-intervention measurements (6 and 24 months after the intervention) were made in clinical practice (follow-up II and III) during the morning shift. Critical care nurses' HH adherence (e.g., HH indications before and after patient contacts, HH technique, duration of handrubbing after applying disinfectant, use of gloves, and other aspects of HH) were measured only during

endotracheal suctioning events (high-risk contacts) using a direct, non-participatory method of observation, which is defined as the gold standard by the World Health Organization. [11]

The method was guided by a validated (S-CVI 0.99), highly structured Ventilator Bundle Observation Schedule (VBOS). Identical measurements were taken for the intervention and control groups by the same trained and experienced observers. If a participant behaved correctly, they were assigned one point, yielding a HH adherence score ranging from 0 to 12. [27] The intraclass correlation coefficient (ICC), including 95 % confidence interval (CI), and the Cohen kappa coefficient (κ) of each item and the average scale score (VBOS) were tested using a second observer during data collection. The ICC of average scale score was >0.9 (95 % CI 0.9–1.0). In addition, the Cohen κ of each item varied from 0.7 to 1.0, demonstrating substantial or perfect agreement. [28]

The level of critical care nurses' knowledge of current HH guidelines [11] was evaluated at the end of each observational sessions using a validated (S-CVI 1.0) Ventilator Bundle Questionnaire (VBQ). The method was guided by a blinded research assistant, who arranged an appropriate time and venue to gather the responses. If a participant answered correctly, they scored one point, yielding a HH knowledge score ranging from 0 to 2. [27]

Statistical analysis

The statistical analysis was performed using SPSS 18.0 for Windows (SPSS INC., Chicago, IL) or SAS (version 9.3. SAS Institute Inc., Cary, NC, USA). The repeatedly measured data was analyzed using a linear mixed model with a covariance pattern model (continuous variables) or by generalized linear mixed model (categorical/dichotomous variables). *P* values reported for repeatedly measured data are as follows: p-time (p_t), the overall change over time; p-group (p_g), the average between-group difference; and p-time*group (p_{t*g}), the interaction between time and group. All participants were included in the groups to which they were originally assigned (intention-to-treat analysis). A two-tailed *P* value less than 0.05 was considered statistically significant.

RESULTS

Thirty (n = 30) out of forty (n = 40) initially randomized critical care nurses participated in the baseline measurements, of whom seventeen (n = 17) completed all the study procedures. Most of the participants were female (70%), having a bachelor's degree in nursing (96.7%) and permanent employment status (66.7%). The mean age was 35.0 years (SD 10.4). The mean experience in the current ICU was 9.5 years (SD 8.7). In addition, 50.0% of participants had received education on infection control within the last 12 months. After baseline measurement, the reasons for withdrawal from the intervention group were sudden illness (n = 1), job transfer (n = 1), declining to participate (n = 1), and not known (n = 1). The main reasons for withdrawal from the control group were declining to participate (n = 3), sudden illness (n = 2), other reasons (n = 2), and job transfer (n = 2).

Critical care nurses' knowledge

During the study period, the average knowledge scores in the intervention group decreased from 60.0% to 40.0% of the total score in the final post-intervention measurement. However, the generalized linear mixed model did not identify any significant time or time-group interactions between the study groups after two years of simulation education.

Critical care nurses' adherence

The average HH adherence score in the intervention group increased from 40.8% (baseline) to 59.2% (follow-up II) and then deteriorated to 50.8% (p_t = 0.002) of the total score in the final post-intervention measurement (follow-up III). According to the linear mixed model, there were no significant group or time-group interactions between the study groups after two years of simulation education, even though the control group had higher HH adherence throughout the whole study period (Table 1).

During the study period, intervention group HH adherence increased from 60.0% to 72.7% (p = 0.69) before patient contact and 20.0% to 70.0% (p = 0.13) after patient contact (Figure 1). In addition, the median duration of handrubbing before [7 (25^{th} – 75^{th} pct 6 – 14.5) vs. 14.5 (25^{th} – 75^{th} pct 10 – 15) seconds, p = 0.010] and after [8 (25^{th} – 75^{th} pct 2.5 – 22) vs. 20 (25^{th} – 75^{th} pct 14 – 25) seconds, p = 0.076] patient contact increased in the final post-intervention measurement (Figure 2). However, a majority of values before (13.3% vs. 18.2%) and after (33.5% vs. 45.5%) patient contact remained below the recommended limit (Figure 2). In the intervention group, rotational rubbing of thumbs increased from 46.7% to 63.6% before patient contact and 46.7% to a high of 90.9% after patient contact in the final post-intervention

measurement. However, rotational rubbing with clasped fingers before (13.3% vs. 18.2%) and after (33.3% vs. 27.3%) patient contacts were still not consistently followed (Figure 3).

DISCUSSION

According to our best knowledge, this is the first longitudinal, parallel, RCT with repeated measurement, conducted to evaluate how critical care nurses' HH practices differ between randomly allocated intervention and control groups before and after simulation education in both the simulation setting and clinical practice. The study findings demonstrated that critical care nurses' knowledge of and adherence to every aspect of current HH guidelines was poor. In addition, our results demonstrated that a single educational intervention, without audiovisual feedback and retraining possibilities, achieved only minor and temporary effects.

The average HH knowledge score in the baseline measurement was 60% of the total score, which is in line with previous studies reporting knowledge scores ranging from 29% to 74% of the total score. [17, 19] The variability of findings among the published studies might be due to differences between the demographic characteristics of participants, whereas the level of ICU experience (< 5 yrs), age (≥ 40), and gender (female) have been independently associated with higher knowledge scores. [11, 29] The level of knowledge was especially disappointing because the majority of participants reported that they had received education on infection control during the last 12 months and had more than 5 years ICU experience.

In the baseline measurement, the average HH adherence score was 40.8% of the total score, which is line with previous studies reporting adherence scores ranging from a low of 6% to a high of 65%. [5–6, 12–15] According to Talbot *et al.*, however, general HH adherence should be at least 75% of the total score before the incidence of device-associated HAIs will decrease. [30] In our study, unfortunately, the required level was not achieved at baseline. Moreover, only 9% of the participants achieved it in the final post-intervention measurement. The level of HH adherence was especially disappointing because several factors influencing good HH adherence existed (e.g., awareness of being observed, type of unit, weekday morning shift, high-risk contact, female gender, participation in previous HH campaign). [11]

The effectiveness of HH on the prevention of HAIs is not only dependent on adherence but also on the proper HH technique (involves five simple and effective steps) and adequate duration (20–30 seconds) of HH action. [11] In our study, however, adherence to every aspect of current HH guidelines was poor (Table 1). Interestingly, on the other hand, several aspects of HH were higher after than before patient contacts, which may suggest a tendency for ritualized behavior mainly performed for self-protection rather than protection of patients from cross-infections. [2]

During the study period, the overall HH adherence increased only by 10 percentage points. This non-significant result was inconsistent with the findings reported by other researchers. [20, 22–24, 30–33] In previous studies, promising results have been obtained after combining the following training tools and strategies: pre-course materials (e.g., e-learning, articles, textbooks) and assessments, didactic lectures, hands-on-experiences with a patient simulator, audiovisual

feedback (e.g., video review, immediate, tailored feedback) and retraining and reassessment possibilities in simulation training. The positive results from these efforts clearly indicate that the employed methods would provide more significant and long-lasting improvements than a single verbal debriefing without any retraining or reassessment possibilities used in this trial. [20, 22–24, 30–33] However, the overall amount of training time to achieve minimum competency standards is unknown. [31–33]

In this study, the main and clear limitation and potential source for bias is related to limited sample size which was, however, based on power analysis. The study was conducted in a single center and the number of dropouts was substantial, which may limit the generalizability of the results. In addition, the study design was not in keeping with what we nowadays know to be the best practices in simulation education. Unfortunately, follow-up simulation education, which could potentially improve our disappointing results, was not possible in our study approach.

In the future, more attention should be paid to well-defined goals and audiovisual feedback, which would allow participants to view and reflect upon their performances. Moreover, participants should identify their errors and should then be allowed to practice those steps they missed. [34–35] In addition, more attention should be paid to regularly repeated educational sessions, which have been associated with significant improvements in HCWs' infection control practices. [20, 22, 24, 31–33, 36]

ACKNOWLEDGEMENTS

The authors thank SimLab personnel from Oulu University of Applied Science and a study nurse Sinikka Sälkiö for their valuable help during data collection. In addition, all of the critical care nurses who participated in this study are respectfully acknowledged.

REFERENCES

1. Ylipalosaari P, Ala-Kokko TI, Laurila J, Ohtonen P, Syrjälä H. Intensive care acquired infection is an independent risk factor for hospital mortality: a prospective cohort study. Critical Care 2006; 10: R66.
2. Wilson S, Jacob CJ, Powell D. Behavior-change interventions to improve hand-hygiene practice: a review of alternatives to education. Critical Pub Health 2011; 21: 119-127.
3. Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. Estimating he proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs. ICHE 2011; 32: 101-114.
4. Wenzel RP, Thompson RL, Landry SM, et al. Hospital-acquired infections in intensive care unit patients: an overview with emphasis on epidemics. Infect Control 1983; 4: 371-375.
5. McGuckin M, Waterman R, Govednik J. Hand hygiene compliance rates in the United States: a one-year multicenter collaboration using product/volume usage measurement and feedback. Am J Med Quality 2009; 24: 205-213.
6. Bingham M, Ashley J, De Jong M, Swift C. Implementing a unit-level intervention to reduce the probability of ventilator-associated pneumonia. Nurs Res 2010; 59: S40-S47.
7. Lobo RD, Levin AS, Oliveira MS, et al. Evaluation of interventions to reduce catheter-associated bloodstream infection: continuous tailored education versus one basic lecture. Am J Inf Control 2010; 38: 440-448.
8. Nteli C, Galanis P, Koumpagioti D, et al. Assessing the effectiveness of an educational program on compliance with hand hygiene in a pediatric intensive care unit. Advances in Nursing 2014; 7: 1-4.
9. Gould DJ, Moralejo D, Drey N. Interventions to improve hand hygiene compliance in patient care. Cochrane Database Syst Rev 2010; 8:CD005186.
10. Siegel JD, Rhinehart E, Jackson M, Chiarello L. Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings. Centers for Disease Control and Prevention. http://www.cdc.gov/hicpac/2007IP/2007isolationPrecautions.html. Published 2007. Accessed September 3, 2015.
11. World Health Organization. WHO guidelines on hand hygiene in health care. First global patient safety challenge clean care is safer care. http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf. Published 2009. Accessed September 3, 2015.

12. Marra AR, Moura DR Jr, Paes AT, dos Santos OF, Edmond MB. Measuring rates of hand hygiene adherence in the intensive care setting: a comparative study of direct observation, product usage, and electronic counting devices. Inf Control Hosp Infect 2010; 31: 796-801.
13. Sahay S, Panja S, Ray S, Rao BK. Diurnal variation in hand hygiene compliance in a tertiary level multidisciplinary intensive care unit. Am J Inf Control 2010; 38: 535-539.
14. Sharma S, Sharma S, Puri S, Whig J. Hand hygiene compliance in the intensive care units of a tertiary care hospital. Ind J Comm Med 2011; 36: 217-221.
15. Gatell MRJ, Roig MS, Vian OH, Santin EC, Duaso CT, Moreno IF & Daunis JV. Assessment of a training programme for the prevention of ventilator-associated pneumonia. Nurs Crit Care 2012; 17: 285-292.
16. Eiamsitrakoon T, Apisarnthanarak A, Nuallaong W, Khawcharoenporn T, Mundy LM. Hand hygiene behavior: Translating behavioral research into infection control. Inf Control Hosp Infect 2013; 34: 1137-1145.
17. De Wandel D, Maes L, Labeau S, Vereecken C, Blot S. Behavioral determinants of hand hygiene compliance in intensive care units. Am J Inf Control 2010; 19: 230-239.
18. Jansson M, Ala-Kokko T, Syrjälä H, Ylipalosaari P, Kyngäs H. Critical care nurses' knowledge of, adherence to and barriers toward evidence-based guidelines for the prevention of ventilator-associated pneumonia – A survey study. Intensive Crit Care Nurs 2013; 29: 216-227.
19. Tromp M, Huis A, de Guchteneire I, et al. The short-term and long-term effectiveness of a multidisciplinary hand hygiene improvement program. Am J Inf Control 2012; 40: 732-736.
20. Carrigo RM, Coty MB, Goss LK, Lajoie AS. Changing health care worker behavior in relation to respiratory disease transmission with a novel training approach that uses biosimulation. Am J Inf Control 2007; 35: 14-19.
21. Jansson M, Ala-Kokko T, Ohtonen P, Meriläinen M, Syrjälä H, Kyngäs H. Effectiveness of human patient simulation education in the nursing management of the mechanically ventilated patient – a randomized controlled trial. Am J Inf Control 2014; 42: 271-276.
22. Sekiguchi H, Tokita JE, Minami T, Eisen LA, Mayo PH, Narasimhan M. A prerotational, simulation-based workshop improves the safety of central venous catheter insertion: results of a successful internal medicine house staff training program. CHEST 2011; 140: 652-658
23. Latif RK, Bautista AF, Memon SB. Teaching aseptic technique for central venous access under ultrasound guidance: A randomized trial comparing didactic training alone to didactic plus simulation-based training. Anesth Analg 2012; 114: 626-633

24. Gerolemou L, Fidellaga A, Rose K, et al. Simulation-based training for nurses in sterile techniques during central vein catheterization. Ame J Crit Care 2014; 23: 40-48.
25. Jansson M, Kyngäs H, Kääriäinen M. Effectiveness of human patient simulation education in improving infection control practices – a systematic review. J Nurs Educ Pract 2014; 4: 1-6.
26. Koff MD, Corwin HL, Beach ML, Surgenor SD, Loftus RW. Reduction in ventilator associated pneumonia in a mixed intensive care unit after initiation of a novel hand hygiene program. J Crit Care 2010; 26: 489-495.
27. Jansson M, Ala-Kokko T, Syrjälä H, Kyngäs H. Development and psychometric testing of Ventilator Bundle Questionnaire and Observation Schedule. Am J Inf Control 2014; 42: 381-384.
28. Landis J & Koch G. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159-174.
29. Fulbrook P, Albarran JW, Baktoft B & Sidebottom B. A survey of European intensive care nurses' knowledge levels. Int J Nurs Stud 2012; 49: 191-200.
30. McGaghie WC, Issenberg B, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. Acad Med 2011; 86: 706-711.
31. Burden AR., Torjman MC, Jaffe JD, et al. Prevention of central venous catheter-related bloodstream infections: is it time to add simulation training to the prevention bundle? J Clin Anesth 2012; 24: 555-560.
32. Wayne DB, Butter J, Siddall VJ, et al. Mastery learning of advanced cardiac life support skills by internal medicine residents using simulation technology and deliberate practice. J Gen Intern Med 2006; 21: 251-256.
33. Sullivan NJ, Duval-Arnould J, Twilley M, et al. Simulation exercise to improve retention of cardiopulmonary resuscitation priorities for in-hospital cardiac arrest: A randomized controlled trial. Resuscit 2015; 86: 6-13.
34. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med 2004; 79: S70-S81.
35. Ericsson KA. Deliberate practice and acquisition of expert performance: a general overview. Acad Emerg Med 2008; 15: 988-994.
36. Beam EL, Gibbs SG, Hewlett AL, Iwen PC, Nuss SL, Smith PW. Method for investigating nursing behaviors related to isolation care. Am J Inf Control 2014; 42: 1152-1156.

TABLE 1. Critical care nurses' hand hygiene practices before and after simulation education.

	Baseline [1]		Follow-up I [1] (3 months after the intervention)		Follow-up II [2] (6 months after the intervention)		Follow-up III [2] (24 months after the intervention)		(p_t) [3]	(p_g) [4]	(p_{t*g}) [5]
	Intervention group (n = 15)	Control group (n = 15)	Intervention group (n = 13)	Control group (n = 12)	Intervention group (n = 13)	Control group (n = 10)	Intervention group (n = 11)	Control group (n = 6)			
Total score (range, 0–12)	4.9 (1.5)	5.2 (2.2)	4.6 (1.2)	4.7 (1.1)	7.1 (1.9)	5.5 (1.9)	6.1 (2.2)	6.8 (2.3)	0.002	0.77	0.
High-risk contact:											
Indications for hand hygiene *n* (%)											
Before patient contact	9 (60.0)	11 (73.3)	6 (46.2)	11 (91.7)	10 (76.9)	9 (90.0)	8 (72.7)	5 (83.3)			
After patient contact	3 (20.0)	2 (13.3)	7 (53.8)	4 (33.3)	10 (76.9)	4 (40.0)	7 (70.0)	3 (50.0)			
Hand hygiene technique *n* (%)											
Before patient contact	2 (13.3)	4 (26.7)	1 (7.7)	3 (25.0)	3 (23.1)	0 (0.0)	2 (18.2)	2 (33.3)			
Rubbing palm to palm	14 (93.3)	13 (86.7)	6 (46.2)	11 (91.7)	13 (100.0)	10 (100.0)	9 (81.8)	6 (100.0)			
Rubbing palm over dorsum	12 (80.0)	12 (80.0)	5 (38.5)	8 (66.7)	13 (100.0)	10 (100.0)	9 (81.8)	6 (100.0)			
Rubbing fingers interlaced	13 (86.7)	12 (80.0)	6 (46.2)	9 (75.0)	13 (100.0)	8 (80.0)	9 (81.8)	6 (100.0)			
Rotational rubbing with clasped fingers	2 (13.3)	5 (33.3)	0 (0.0)	2 (16.7)	4 (30.8)	0 (0.0)	2 (18.2)	1 (16.7)			
Rotational rubbing of thumbs	7 (46.7)	12 (80.0)	4 (30.8)	9 (75.0)	9 (69.2)	6 (60.0)	7 (63.6)	6 (100.0)			
After patient contact	5 (33.3)	5 (33.3)	4 (30.8)	1 (6.7)	4 (30.8)	0 (0.0)	5 (45.5)	2 (33.3)			
Rubbing palm to palm	13 (86.7)	9 (60.0)	8 (61.5)	7 (58.3)	13 (100.0)	10 (100.0)	11 (100.0)	5 (83.3)			
Rubbing palm over dorsum	13 (86.7)	8 (53.3)	8 (61.5)	6 (50.0)	13 (100.0)	9 (90.0)	11 (100.0)	5 (83.3)			
Rubbing fingers interlaced	11 (73.3)	9 (60.0)	7 (53.8)	4 (33.3)	13 (100.0)	8 (80.0)	11 (100.0)	5 (83.3)			
Rotational rubbing with clasped fingers	5 (33.3)	5 (33.3)	3 (23.1)	1 (8.3)	3 (23.1)	0 (0.0)	3 (27.3)	1 (16.7)			

Rotational rubbing of thumbs	7 (46.7)	9 (60.0)	11 (84.6)	5 (41.7)	11 (84.6)	5 (50.0)	10 (90.9)	5 (83.3)
Duration of handrubbing (20–30sec)								
Before patient contact	2 (13.3)	6 (40.0)	0 (0.0)	2 (16.7)	7 (53.8)	4 (40.0)	2 (18.2)	2 (33.3)
After patient contact	5 (33.3)	4 (26.7)	1 (7.7)	2 (16.7)	7 (53.8)	1 (10.0)	5 (45.5)	3 (50.0)
Other aspects of hand hygiene								
Keep natural nails short *n* (%)	10 (66.7)	11 (73.3)	9 (69.2)	7 (58.3)	9 (69.2)	7 (70.0)	9 (81.8)	6 (100.0)
Remove rings, watch, and bracelets *n* (%)	14 (93.3)	14 (93.3)	11 (84.6)	10 (83.3)	13 (100.0)	10 (100.0)	11 (100.0)	5 (83.3)
Used gloves disposed of in a manner that prevents contamination from secretions *n* (%)	5 (33.0)	3 (20.0)	5 (38.5)	2 (16.7)	11 (84.6)	7 (70.0)	4 (36.4)	3 (50.0)

[1] Simulation setting. [2] Clinical practice. NOTE. Values for total score are given as mean (SD). Values (valid percent) for compliance are presented as *n* (%). *P* values reported for repeatedly measured dat

are as follows: [3] the overall change over time (p_t), [4] the average group difference (p_g) and [5] the interaction between time and group (p_{t*g}). A $P < 0.05$ is considered significant.

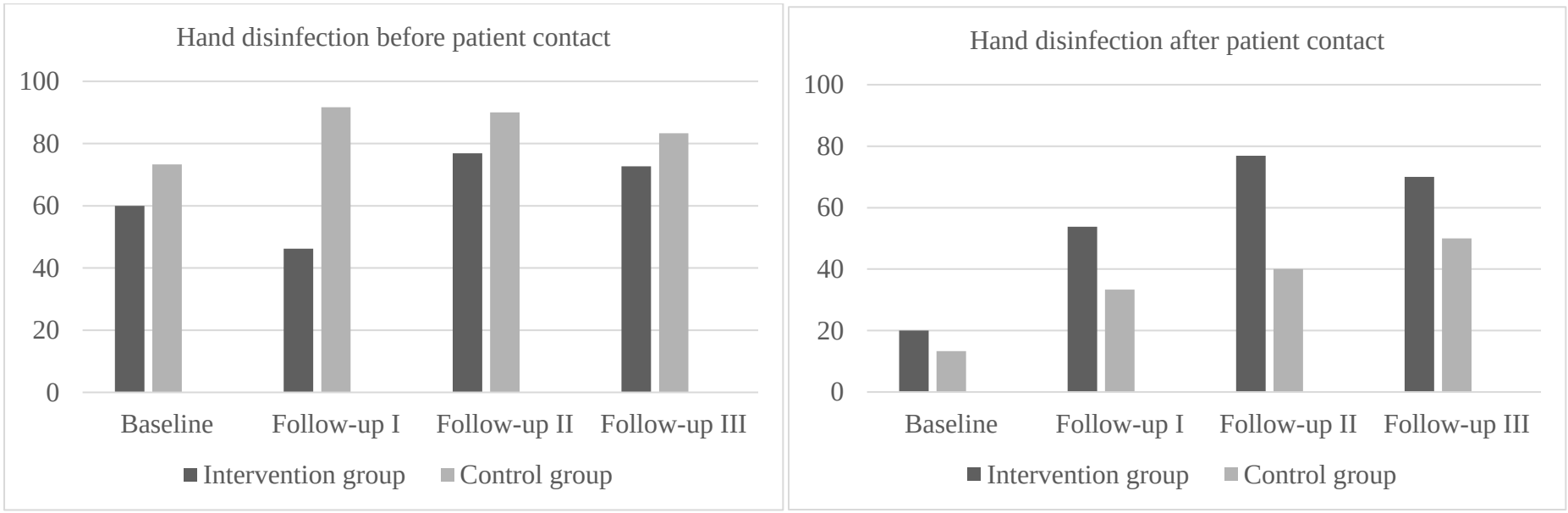

FIGURE 1. Critical care nurses' adherence to handrubbing before and after simulation education remained below targeted behavior rates**.** The baseline and initial post intervention measurements (3 months after the intervention) were conducted in the simulation environment (follow-up I). The final post intervention measurements (6 and 24 months after the intervention) were made during the morning shift (7 AM – 3 PM) in clinical practice (follow-up II – III).Values are given as percentage rates.

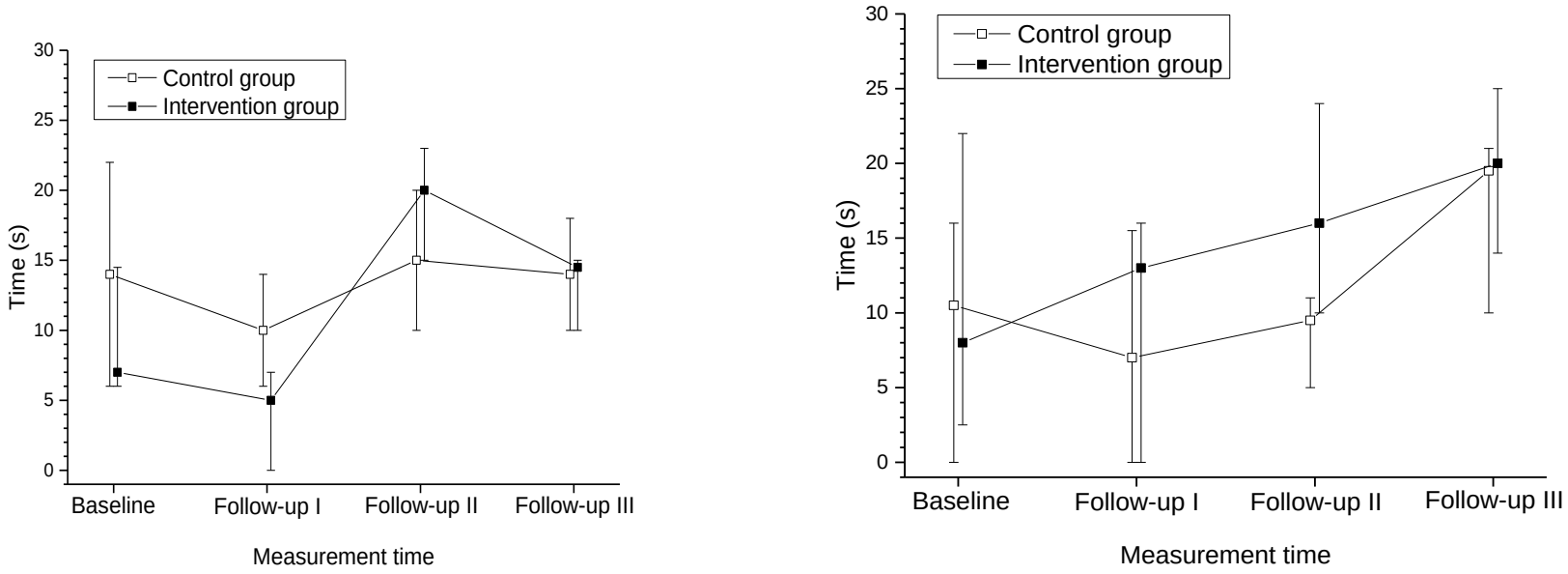

FIGURE 2. The duration of handrubbing before and after simulation education remained below the recommended limit of 20 – 30 seconds. The baseline and initial postintervention measurements (3 months after the intervention) were conducted in the simulation environment (follow-up I). The final post intervention measurements (6 and 24 months after the intervention) were made during the morning shift (7 AM – 3 PM) in clinical practice (follow-up II – III). Values are given as seconds.

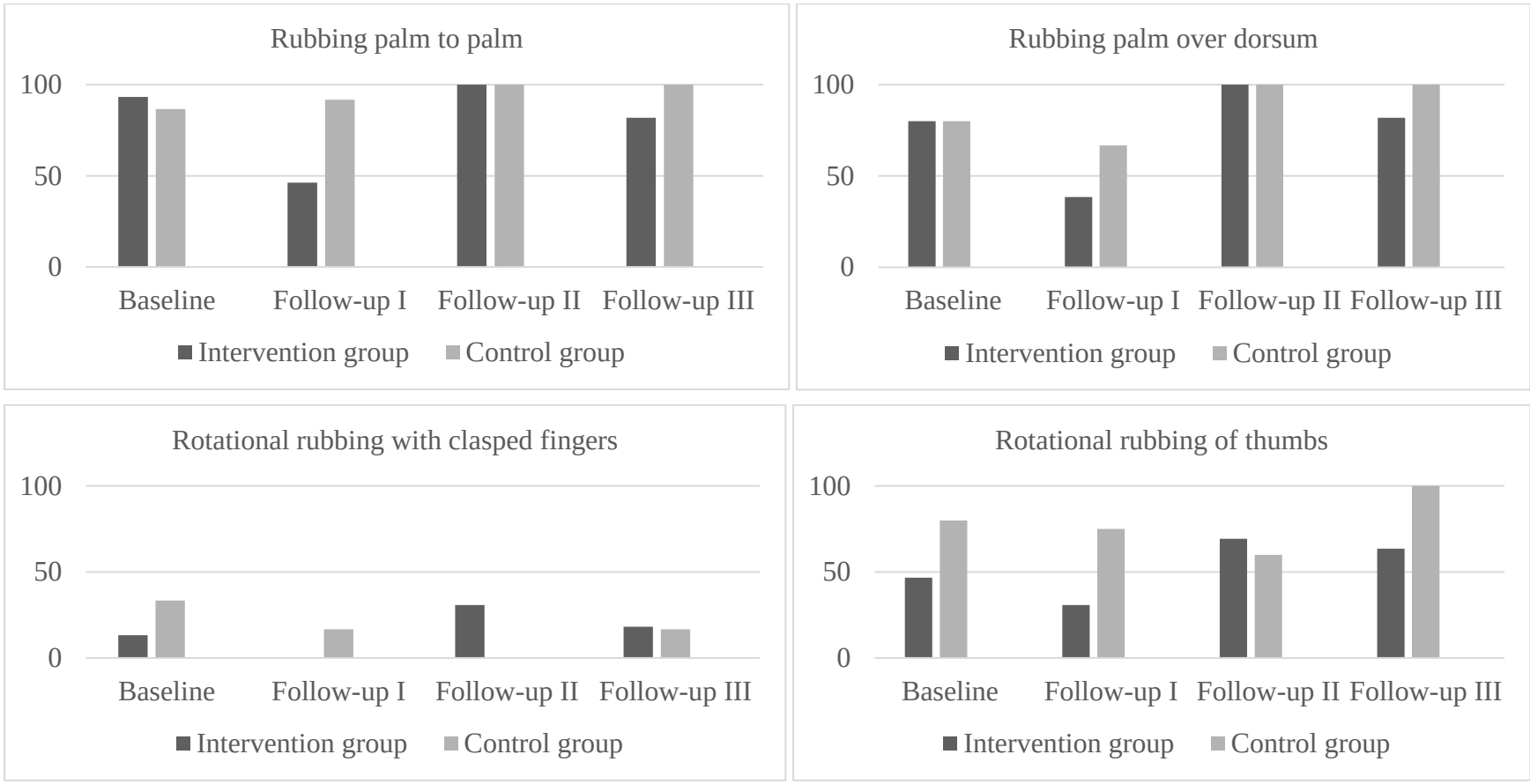

FIGURE 3. Proper hand hygiene technique was followed before patient contact, except for rotational rubbing of thumbs and rotational rubbing with clasped fingers, which were improperly executed. The baseline and initial postintervention measurements (3 months after the intervention) were conducted in the simulation environment (follow-up I). The final post intervention measurements (6 and 24 months after the intervention) were made during the morning shift (7 AM – 3 PM) in clinical practice (post-tests II – III).Values are given as percentage rates.