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Effectiveness of Simulation-Based Education for Caring Patients with COVID-19

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Purpose: The role of medical staff gained immense significance in the context of the prolonged coronavirus disease (COVID-19) pandemic. However, few studies had explored the impact of simulation-based education on the ability of nursing students to care for the patients of COVID-19. This study provided nursing students with simulation-based education in caring for the patients of COVID-19 and confirmed its effectiveness. **Methods:** This study used a non-equivalent control group pretest-posttest design. The participants were recruited from the nursing departments of two universities in Korea through convenience sampling. A total of 79 participants were included: 37 in the intervention group and 42 in the control group. The intervention group received four sessions of simulation training based on the National League for Nursing Jeffries simulation theory. **Results:** The intervention group showed an improvement compared to the control group in terms of knowledge related to coronavirus, confidence in performing infection control skills, and perception of preparedness for caring for the patients of COVID-19, with a high-level of satisfaction and self-confidence in learning. There was no significant difference between the two groups in terms of anxiety. **Conclusion:** This simulation is expected to be a significant strategy for alleviating the global burden in terms of staff safety and patient outcomes by improving the competencies of prospective medical staff in responding to pandemics.

Key words: Students, Nursing; Education; Simulation Training; COVID-19; Nursing Theory

INTRODUCTION

Since early 2020, the coronavirus disease (COVID-19) has had a devastating impact on the health and life of the global population. To date, approximately 770 million confirmed cases and 6.9 million deaths have been reported worldwide [1]. The impact of the COVID-19 pandemic as well as the threat of new infectious diseases constitute a constant concern for the world, necessitating preparations to respond to future health crises. During the pandemic, healthcare workers struggled to cope with infectious diseases [2]. Studies have revealed the difficulties nurses experienced because of inadequate preparation and inexperience in dealing with such an outbreak [2]. Particularly, as nurses play a crucial role in preventing the spread of infectious diseases, lack of preparation leads to negative consequences including threats to safety of patient and staff, as well as public health crises. Additionally, nursing students represent the future healthcare workforce, which will possibly care for patients of highly infectious diseases such as COVID-19.

Preparation and training to care for the patients of COVID-19 is crucial because inappropriate infection control practices increase the risk of exposure to infectious diseases. As nursing students lack clinical experience and expertise, they may have poorer skills in nursing patients infected with high-risk pathogens [3]. Wu et al. [4] reported the low level of knowledge of standard precautions among Taiwanese nursing students and limited ability to apply these precau-

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tions in clinical practice. Similarly, in other studies, the correct answer rate of knowledge of infection prevention and control among nursing students was 59.8% [5], and their COVID-19-related knowledge was insufficient [6].

A key strategy for improving the infection control practices of prospective medical personnel is to enable medical students develop appropriate practices early on, and educate them to reinforce these skills [7]. Appropriate infection control necessitates improvements in both theoretical knowledge and performance in clinical situations. However, a systematic review revealed that infection control education among nursing students tends to emphasize teaching methods based on theoretical elements, excluding infection control practices [8]. Considering the emerging threat of new infectious diseases, it is crucial that nursing education improves the infection controlling competency of nursing students, which requires an effective educational method.

Many studies have shown that simulation-based education is effective in improving the knowledge, skills, anxiety, preparedness, satisfaction, and confidence of prospective medical professionals in clinical situations [9,10]. Nursing students who completed two weeks of simulation training consistently performed better in clinical settings than those who had not attended simulation [11]. Prospective medical personnel could acquire knowledge and skills through simulation-based education and apply them to virtual clinical situations, thereby integrating and improving their core competencies. Furthermore, studies have shown that healthcare workers experienced psychological issues such as anxiety and distress during the pandemic, and that training, education, and high self-efficacy in caring for patients is associated with good mental health [12]. In this context, providing appropriate training for nurses and nursing students in caring for patients with high-risk pathogens would help alleviate negative emotions such as anxiety [12]. Therefore, simulation-based education can be a significant method to appropriately provide nursing care to patients infected with high-risk pathogens, and would be helpful in mentally preparing nursing students for pandemic situations.

However, in previous studies, simulation-based education for caring for the patients of COVID-19 was mainly conducted among healthcare workers. Therefore, the effectiveness of simulation-based education on infection control for nursing students remains largely unknown [13] and the theoretical framework recommended to effectively develop, implement, and evaluate simulations was not used in the studies among nursing students [14]. A previous study developed and evaluated a simulation module based on a theoretical framework for nursing students; however, confirmation of the intervention effect was limited as it was a one-group pretest-posttest study [15].

Evidence on whether simulation-based education is effective in enhancing nursing students' ability to care for patients of COVID-19 is scarce. Therefore, this study applied a simulation education program based on the National League for Nursing (NLN) Jeffries simulation theory [16] to nursing students and sought to verify its effectiveness. We focused on knowledge, anxiety, confidence in infection control practices, and perception of preparedness for caring for patients of COVID-19, based on the simulation framework. The following hypotheses were investigated: (1) participants receiving simulation-based education would show significant improvement in their level of knowledge, confidence in infection control practice, anxiety, and perception of preparedness than those in the control group; and (2) individuals in the intervention group would have high satisfaction and self-confidence.

METHODS

1. Study design and sample

This study adopted a non-equivalent control group pretest-posttest design to verify the effects of simulation-based education for nursing students on their knowledge, anxiety, confidence in infection control practice, and perception of the preparedness for caring for the patients of COVID-19.

The participants included senior nursing students recruited from the nursing departments of two universities in Korea through convenience sampling. Exclusion criteria were: (1) those who had previously participated in simulation-based education regarding caring for patients of COVID-19 and (2) those who had actual experience in caring for patients of

COVID-19. To prevent the diffusion of experimental effects and consider the feasibility, nursing students attending Dong-A University and Dongguk University were assigned to the intervention and control groups, respectively. As the intervention included an educational program, and considering the measurement variables, the research could not be double-blinded.

In the research plan, we calculated a sample size of 60 participants in each group by using an independent t-test with the power of 0.8, significance level of 0.05, and effect size (Cohen's d) of 0.52, which is the effect size on knowledge level in a study regarding simulation education [17]. Considering a dropout rate of 10%, we intended to recruit 66 participants in each group at first. After recruitment and dropout, 37 participants in the intervention group, and 42 in the control group were included for in the final analysis (See Supplementary Figure 1). These satisfied the cut-off of 71 persons as the minimum sample size based on the pre- and post-test values on knowledge levels in a study that validated the effectiveness of educational interventions, including simulations on infection control precautions among nursing students [18]. This sample size was calculated using the power of 0.8 and significance level of 0.05, delta value of 1.2, standard deviation of 1.5, and correlation of 0.5 obtained after the Generalized Estimated Equation (GEE) tests for the slope of two groups in a repeated measures design (continuous outcome) using the Power Analysis and Sample Size software 2023 [19]. Furthermore, to assess the adequacy of the sample size in this study, a post-hoc power analysis was conducted. The results revealed that for the variables that showed significance, the power ranged from 0.98 to 1.00. Therefore, it was considered that the participants included in this study were deemed appropriate.

2. Procedures

The application and evaluation of simulation-based education was conducted from October to December 2021. Participants were recruited via the online group chat rooms of senior-year students from October 10 to November 3. A recruitment announcement was posted in the group chat rooms, specifying, among other things, the purpose and content of the study and voluntary nature of participation. An online Google Forms survey link was also provided to enable the willing participants access the survey. Upon accessing the link, they were first presented with an explanation of the study and asked for their consent. If they did not agree to participate, the survey was automatically closed. Owing to the online-based recruitment approach and the voluntary nature of participation, it was difficult to recruit the desired sample size as planned. As this study involved students' participation, extra attention was paid to ensure autonomy in participation, which is ethically significant. Additionally, the COVID-19-related restrictions caused administrative limitations in conducting face-to-face interventions for students who were not affiliated with the researcher's institution. Therefore, we were unable to achieve the planned sample size.

After enrollment, students from Dong-A University and Dongguk University, who voluntarily agreed to participate in the study, were assigned to the intervention and control groups, respectively to complete the pretest survey. After the completion of the simulation-based training, the intervention group was administered a posttest survey. In contrast, the control group was administered a posttest survey four weeks later, and without any treatment.

3. Simulation-based education on caring for patients of COVID-19

This study is based on the NLN Jeffries simulation theory [16]. We designed and developed simulation-based education comprising components of the NLN Jeffries simulation theory [16] by reviewing infection control guidelines related to COVID-19 and seeking advice from the infection control unit at a university hospital in Seoul that specialized in treating patients of COVID-19.

The scenario was a case where a patient diagnosed with COVID-19 shows symptoms of high fever, is hospitalized in an isolation room, and complains of dyspnea and feelings of isolation and anxiety (Table 1). The learning goals were: "I can identify the nursing needs and problems of COVID-19 patients"; "I can apply nursing interventions according to the nursing plan to patients with COVID-19"; and "I can select

Table 1. Scenario Progression

Patient state	Objectives	Expected learner actions	Specific infection control practices
1. Initial state Complaint of fever, cough, and dyspnea	• Students will be able to assess the patient • Students will be able to provide nursing intervention to the patient • Students will be able to comply infection control practice to care the isolated patient	• Nursing assessment • Planning and implementing nursing intervention: dyspnea, fever • Infection control practice	• Performing hand hygiene • Understanding structure and function of negative pressure room • Distinguishing between general areas, anteroom and isolation room • Complying isolation precaution • Donning PPE • Handling sharps
2. Secondary state Complaint of anxiety and isolation feeling	• Students will be able to provide the psychosocial interventions for the isolated patient	• Nursing assessment • Providing psychosocial support • Patient education: information	• Psychosocial support for isolated patients
3. Final state Subsiding of symptoms or deteriorating status	• Students will be able to evaluate nursing outcomes and patient's response • Students will be able to comply infection control practice to care the isolated patient	• Nursing evaluation • Infection control practice • Patient education: information • Nursing record	• Disposal of infectious waste • Patient education: isolation precaution • Doffing PPE

PPE = Personal protective equipment.

appropriate personal protective equipment (PPE) and accurately perform donning and doffing." During the simulation running, various infection control practices were performed, such as compliance with isolation precautions, proper use of PPE, and management of isolation medical waste (Table 1). While complying with these practices, participants were expected to conduct nursing assessments and implement nursing interventions for the physical problems of the patient. Furthermore, they were required to assess the patient's feelings of isolation and anxiety and provide psychosocial interventions to resolve these problems.

In terms of fidelity, the simulation practice lab was reproduced as an isolation ward, and was divided into the anteroom, ward, and nurse's station. Roles in the situation included one leader nurse who performed nursing proactively, and 2~3 nurses in charge of vital sign measurement, medication administration, nursing intervention, and recording. An instructor (the first author) played the role of a doctor. To resemble an actual clinical situation, it was considered realistic for one participant to play the role of a nurse. However, considering the number of students and training time, and that psychological safety could impact the educational effect in a high-fidelity situation, 2~3 nurses were assigned to each simulation running. The participants voluntarily divided their roles within the team. Scenario background and design included basic information of the module, nursing history, medical order, and examination results; prior nursing knowledge and skills; debriefing plan; and evaluation method, etc.

The simulation-based education lasted eight hours, involving four sessions: pre-lecture for background knowledge, skill practice and preparation for simulation, simulation experience, and post-learning (See Supplementary Table 1). The intervention group was divided into three subsets; each subset was divided into three teams; and each team comprised 4~5 students who attended the simulation at once. In the first session, online lectures were provided with an overview of the simulation module, learning goals, and prior knowledge and skills. The intervention group attended the online session before other sessions. The rest of the sessions were conducted in-person and consecutively, for one day. These sessions were conducted once per week and each subset of the intervention group attended these sessions on the same day; the sessions lasted a total of three weeks. In the second session, a quiz was conducted to ascertain the learning status of the pre-lecture, and training and evaluation of the skill of donning and doffing level D PPE were performed. Additionally, team discussion time was allocated to address the simulation situation. The third session comprised pre-briefing, simulation experience, and debriefing. Each team had two repeated simulation experiences on the developed COVID-19 patient nursing scenario module using the human patient simulator; simulation experience for each team lasted approximately 40 minutes. While one team experienced the simulation, the other observed the simulation their colleagues underwent. The simulation was operated by one professor (the first author) with simulation class experience and one assistant as a clinical instructor who provided technical assistance, helped set up the simulation lab, and supplied materials and supplies during the overall simulation class. After it was over, all subjects who participated in the practice attended a debriefing for 60 minutes. Debriefing was conducted as a group so that they could reflect upon their respective team's experiences and share them with each other. The instructor led the discussion following a structured approach based on the gather, analyze, and summarize (GAS) model [20]. In the final session, participants were asked to consider topics related to the module and check their own values by performing the learning activities. These activities included investigating and summarizing key learning content related to the scenario, and watching a video of a nurse caring for the patients of COVID-19 and reflecting upon the nurse's role. Additionally, they were instructed to reflect upon their own simulation experience and write a reflective journal individually.

4. Measurement

In the NLN Jeffries simulation theory [16], outcomes include participant, patient, and system. According to Jeffries et al. [21], with participants, it is possible to measure outcomes on self-confidence, learner's satisfaction, skills, and knowledge. As such, this study measured primary outcomes including knowledge related to COVID-19, confidence in performing infection controlling skills, and perception of the preparedness for caring for the patients of COVID-19, which were the educational outcomes. Additionally, it assessed satisfaction and self-confidence in learning and anxiety, which were the reactions of students. Nursing students experienced higher levels of anxiety owing to factors such as fear of infection during the pandemic [22]. The high anxiety level had a negative impact on their intention to care for the patients of emerging infectious diseases [23]. Thus, this study investigated the level of anxiety among senior nursing students in the context of the COVID-19 pandemic.

Participant characteristics and primary outcomes were measured in the pretest and posttest surveys. Satisfaction and self-confidence in learning was only measured in the posttest survey of the intervention group. The pretest survey was conducted from October 19 to November 3 for the control and intervention groups. Each of the three subsets in the intervention group conducted posttest survey the day after intervention was completed. The posttest survey of the first subset was conducted three weeks after the preliminary survey, and the second and third subsets conducted survey after five and six weeks, respectively. The posttest survey of the control group was measured four weeks after the preliminary survey—similar to the intervention group—to control for the effects of extraneous variables such as maturation.

1) Characteristics

Age and sex were investigated as general characteristics using a structured questionnaire. Infection control-related characteristics included experience in education regarding emerging infectious diseases and COVID-19 or infection control within one year, and experience of being monitored for wearing PPE.

2) Knowledge related to COVID-19

Knowledge related to COVID-19 was evaluated using a tool developed by Kim [24] based on the guidelines published by the World Health Organization and the Korea Disease Control and Prevention Agency. It comprises 25 questions, including clinical aspects (six items), routes of transmission (three items), symptoms (one item), treatment (three items), diagnosis (three items), management of sample (two items), isolation precautions (three items), and nursing intervention (four items). One point is obtained if the response is correct, and zero if it is incorrect or unknown; the total score ranges from 0 to 25 points. A higher score indicates a higher level of knowledge. The reliability of the developers' study was the Kuder-Richardson Formula 20 (KR-20) = .65 [24], while that of this study was KR-20 = .40 in the pretest and .81 in the posttest survey.

3) Anxiety

Anxiety was measured through a Korean translation of the Generalized Anxiety Disorder 7-item developed by Spitzer et al. [25], which was downloaded free of charge from www.phqscreeners.com [26]. It is a widely used tool for evaluating mental health [27] and was employed to assess the anxiety level of nursing students during the pandemic [22]. It comprises a 4-point Likert scale with a total of seven items, and the total score ranges from 7 to 28 points. A higher score implies a higher degree of anxiety. The reliability of the Korean version of the translated tool for general adults was Cronbach's α = .90 [28]. The reliability of this study was Cronbach's α = .85.

4) Confidence in performing infection control skills

The confidence in performing infection control skills was evaluated by translating and reverse-translating a tool developed by Luctkar-Flude et al. [29]. It comprises seven questions that are rated on a 6-point Likert scale to assess the level of confidence in performing infection control skills, such as applying contact isolation and wearing PPE while caring for the patients of COVID-19. The total score ranges from 7 to 42 points. The reliability of the developers' study was Cronbach's α = .90, while that of this study was Cronbach's α = .85.

5) Perception of preparedness for caring for the patients of COVID-19 (hereafter preparedness)

Preparedness to care for the patients of COVID-19 was measured by translating, reverse-translating, and properly adapting a tool developed by Carvalho et al. [30] and modified by Khan & Kiani [31]. It consists of seven questions that are rated on a 10-point Likert scale (e.g., "I feel ready to participate in the management of patients infected with COVID-19 virus," "If today, I have to take care of a patient infected with COVID-19, I would do it"). The total score ranges from 7 to 70 points, with a higher score implying a higher level of preparedness to care for the patients of COVID-19. The reliability of this study was Cronbach's α = .90.

6) Satisfaction and self-confidence in learning

Satisfaction and self-confidence in learning were measured using a tool developed by the National League for Nursing [32], which was translated into Korean and verified by Yoo [33]. It involves a 5-point Likert scale used to rate five questions regarding satisfaction and eight regarding self-confidence. The total score of satisfaction ranges from 5 to 25 points, that of self-confidence in learning ranges from 8 to 40 points. The reliability of the tool translated into Korean was Cronbach's α = .89 for satisfaction and Cronbach's α = .72 for self-confidence. The reliability of this study was Cronbach's α = .91 for satisfaction and Cronbach's α = .79 for self-confidence.

5. Data analysis

The collected data were analyzed with SPSS version 23.0 (IBM Corp., Armonk, NY, USA) for Windows, and the specific measures were as follows:

1) A descriptive analysis was performed to describe the participants' characteristics and satisfaction and self-confidence in learning.
2) A Kolmogorov-Smirnov test was used for testing normality.
3) The χ^2 test, Fisher's exact test, independent t-test, and Mann-Whitney U test were used to identify homogeneity of characteristics and outcome variables at baseline between the intervention and control groups.
4) Changes in the variables before and after the intervention between both groups were analyzed using the GEE with an unstructured matrix adjusted for anxiety and preparedness, the outcome variables that were not homogenous at the baseline (i.e., adjustment for baseline covariates), and the interval day. The interval day covariate was the pre-post survey interval for each group

(e.g., putting "0" interval day in the pretest and "28" in the posttest among the control group) to identify potential confounding effects. The GEE is generally used to analyze repeated measurements with inappropriate data for normality assumptions while adjusting covariates. Thus, considering the non-homogeneity and non-normality data (e.g., knowledge, anxiety, and confidence variables), the GEE is suitable for this study to test the intervention effects. Additionally, instead of using the means, the estimated marginal means, adjusted for the effects of other variables, were used to compare the effects on the intervention of both groups while controlling for the confounding factors and to evaluate the group × time interaction effect. Additionally, we analyzed the independent t-test to examine the differences in before and after the intervention between groups, regardless of non-normality of the variables in this study, and compared its result with that of the GEE analysis.

6. Ethical considerations

This study received approval from the Dong-A University Institutional Review Board (IRB No. 2-1040709-AB-N-01-202109-HR-065-02). The objective and content of this study were explained to participants, and it was emphasized that there would be no negative repercussions for refusing to participate in this study. After completing the survey, the participants received an electronic gift card.

Table 2. Homogeneity Test of Characteristics and Education Experience between Two Groups at Baseline (*N* = 79)

Variables	Categories	Mean ± SD or n (%)†		t/U/χ^2	*p*
		Int. (n = 37)	Con. (n = 42)		
Characteristics					
Age (years)		22.73 ± 1.79	23.12 ± 2.44	728.50††	.612
Sex	Female	36 (97.3)	37 (88.1)	2.37§	.206
	Male	1 (2.7)	5 (11.9)		
Infection control education experience (within 1 year)	Yes	36 (97.3)	42 (100.0)	1.15§	.468
	No	1 (2.7)	0 (0.0)		
EID education experience	Yes	31 (83.8)	36 (85.7)	0.06	.811
	No	6 (16.2)	6 (14.3)		
COVID-19 education experience (within 1 year)	Yes	34 (91.9)	41 (97.6)	1.34§	.336
	No	3 (8.1)	1 (2.4)		
Contents of COVID-19 infection control education‖	Clinical symptoms and aspects	33 (89.2)	40 (95.2)		
	Routes of transmission	34 (91.9)	40 (95.2)		
	Diagnosis and treatment	25 (67.6)	29 (69.1)		
	Method of sample collection	19 (51.4)	30 (71.4)		
	Method of donning and doffing of PPE	12 (32.4)	14 (33.3)		
	Method of cleaning and disinfecting	11 (29.7)	13 (31.0)		
	Caring for the patient	9 (24.3)	11 (26.2)		
The most effective COVID-19 infection control education method	Lecture	1 (2.7)	0 (0.0)		
	Combination of lecture and practice	34 (91.9)	36 (85.7)		
	Practice	2 (5.4)	6 (14.3)		
Number of COVID-19 education		2.70 ± 2.28	2.57 ± 1.98	758.50††	.852
Experience of being monitored for wearing PPE	Yes	3 (8.1)	8 (19.0)	1.96	.161
	No	34 (91.9)	34 (81.0)		

SD = Standard deviation; Int. = Intervention group; Con. = Control group; EID = Emerging infectious diseases; PPE = Personal protective equipment; COVID-19 = Coronavirus disease-2019.
†Data were presented in n (%) for categorical variables or mean ± SD for continuous variables. ††Mann-Whitney U test. §Fisher's exact test. ‖Multiple response.

RESULTS

The data of 79 participants who completed the posttest survey were included in the analysis: 37 participants from the intervention group, and 42 from the control group.

1. Baseline homogeneity of the intervention and control groups

The average age of the participants was 23.06 ± 2.19 years, and women constituted the majority at 73 (92.4%) of the 79 participants (Table 2). A total of 78 participants (98.7%) had received infection control education within one year, and 75 (94.9%) possessed experience in education related to COVID-19. As for the most effective method of COVID-19 infection control education, 70 (88.6%) answered that it was education combining lecture and practice (Table 2). As mentioned above, there were no statistically significant differences between the intervention and control groups in terms of characteristics.

Among the primary outcomes, knowledge and confidence in performing infection control skills showed no statistically significant difference between the groups, indicating that both groups were homogeneous. However, anxiety was 3.27 ± 3.02 in the intervention group, which was statistically significantly higher than that in the control group (1.36 ± 2.14, p < .001). Additionally, preparedness was 31.95 ± 11.52 in the intervention group, which was significantly lower than that in the control group (44.48 ± 12.37, p < .001). Therefore, baseline anxiety and preparedness were not the same between the two groups (Table 3).

The analysis of the baseline homogeneity between the follow-up and lost to follow-up groups revealed significant differences within the control group: 15 (65.2%) of the 23 participants were women in the lost to follow-up group, and 88.1% in the follow-up group. In terms of outcome variables, the score of knowledge was 17.38 ± 2.13 in the follow-up group, which was significantly higher than that of the lost to follow-up group (16.09 ± 2.41, p = .033). There was no difference between the two groups in terms of the other variables (See Supplementary Table 2).

Table 3. Homogeneity Test and Effect of Intervention on the Outcome Variables of Two Groups† (*N* = 79)

Variables	Pre-test†				Post-test††						
	Mean ± SD or n (%)§		t/U	*p*	Mean ± SD or n (%)§		Source‖	Estimate	SE	Wald χ^2	*p*
	Int. (n = 37)	Con. (n = 42)			Int. (n = 37)	Con. (n = 42)					
Knowledge	17.27 ± 2.56	17.38 ± 2.13	774.00¶	.976	24.00 ± 1.22	18.10 ± 2.64	Intercept	2.765	0.058	2,246.78	< .001
							Group	0.031	0.032	0.98	.323
							Time	0.142	0.038	14.04	< .001
							Group × Time	0.277	0.030	85.54	< .001
Anxiety	3.27 ± 3.02	1.36 ± 2.14	409.50¶	< .001	2.76 ± 2.58	1.05 ± 1.82	Intercept	1.148	0.284	16.30	< .001
							Group	0.241	0.195	1.54	.215
							Time	− 0.063	0.370	0.03	.865
							Group × Time	− 0.205	0.197	1.08	.299
Confidence in performing infection control skills	30.22 ± 4.49	32.36 ± 5.51	601.00¶	.083	35.16 ± 3.72	31.90 ± 5.23	Intercept	3.208	0.056	3,307.75	< .001
							Group	0.019	0.035	0.31	.581
							Time	0.044	0.051	0.73	.394
							Group × Time	0.086	0.031	8.04	.005
Perception of preparedness	31.95 ± 11.52	44.48 ± 12.37	4.639	< .001	49.35 ± 9.49	46.74 ± 14.23	Intercept	3.803	0.045	7,074.01	< .001
							Group	− 0.320	0.074	18.69	< .001
							Time	0.022	0.124	0.032	.857
							Group × Time	0.381	0.060	39.99	< .001

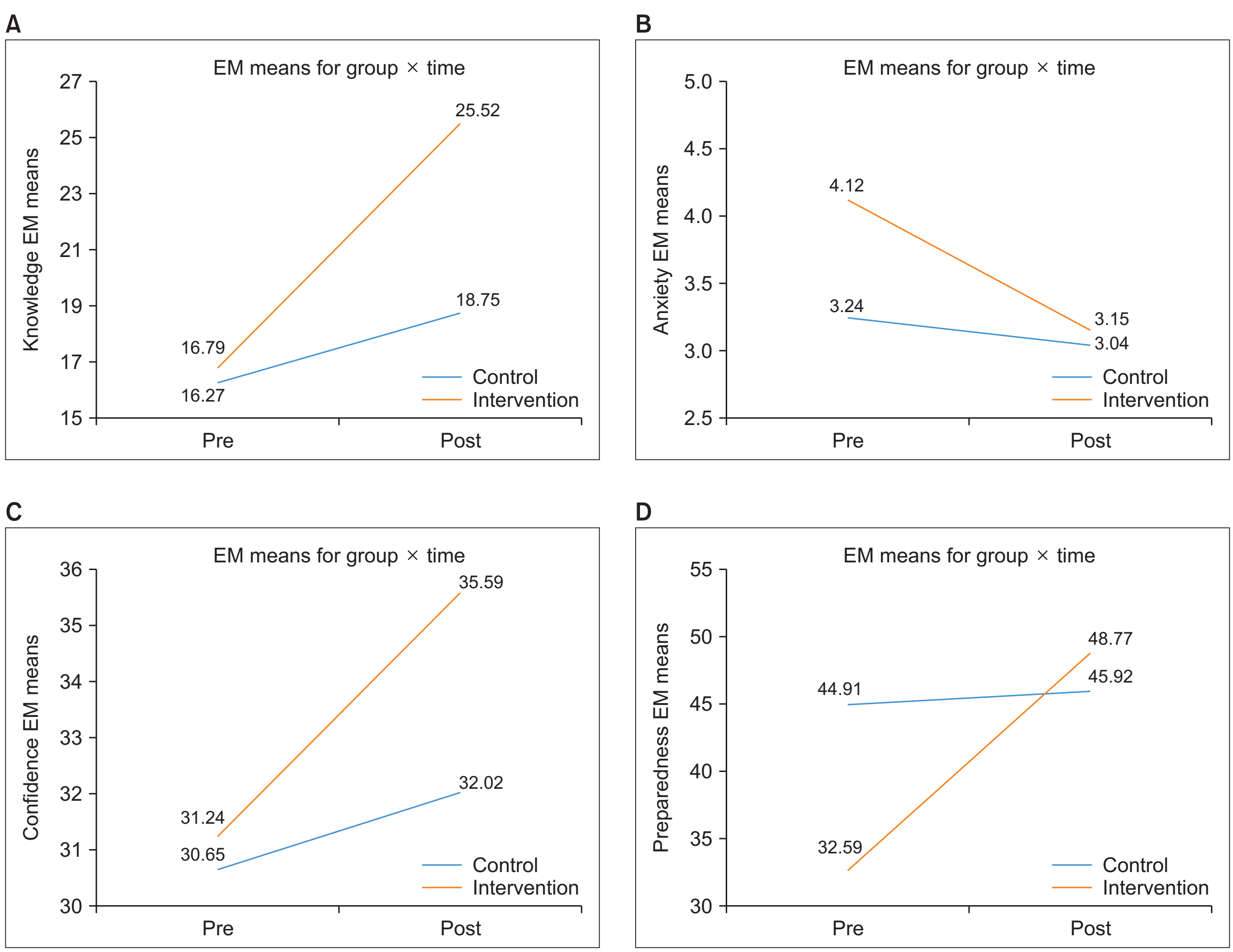
SD = Standard deviation; Int. = Intervention group; Con. = Control group; SE = Standard error.
†Homogeneity test using t-test or Mann-Whitney U test. ††Data were analyzed using generalized estimated equation adjusted for interval day and anxiety, preparedness variables. §Data were presented in n (%) for categorical variables or mean ± SD for continuous variables. ‖Group (reference = "control group"), Time (reference = "baseline, pre"). ¶Mann-Whitney U test.

2. Effect of simulation-based education

The effects of simulation-based education analyzed using the GEE are shown in Table 3, and the changes are shown in Figure 1 as a graph. In both the groups, the knowledge score increased in the posttest compared to the pretest. The knowledge score of the intervention group showed greater improvement from the baseline value compared to that of the control group, with an estimated mean of 25.52 in the posttest (Figure 1). The GEE analysis (Table 3) showed significant group × time interaction effect for knowledge ($p < .001$).

Additionally, the correct answer rate of COVID-19 knowledge was 96.0% in the intervention group and 72.4% in the control group in the posttest, which improved in the intervention group compared to its correct answer rate (69.1%) and that of the control group's (69.5%) during the pretest (See Supplementary Table 3). In particular, there was a significant difference in the correct answer rate between the two groups in the subcategories of sample management [98.6% (intervention group) vs. 35.7% (control group)] and isolation guidelines [95.5% (intervention group) vs. 49.2% (control group)].

Regarding confidence in performing infection control skills, there was a significant difference in the change between both groups over time (p = .005). After the intervention group received simulation-based training, their confidence in



EM = Estimated marginal.

Figure 1. The trend of outcome variables between both groups. (A) Knowledge, (B) anxiety, (C) confidence in performing infection control skills, (D) perception of preparedness.

performing infection control skills significantly improved from 31.24 in the pretest to 35.59 in the posttest compared to the control group.

Regarding preparedness, the GEE results showed a significant difference in the change between the two groups over time ($p < .001$); the intervention group showed a significant improvement from 32.59 in the pretest to 48.77 in the posttest compared to the control group, confirming the effect of simulation-based education on preparedness.

Conversely, in the intervention group, the estimated mean value of anxiety was higher in the pre- and post-surveys than in the control group, and both groups showed a decreasing pattern in the post-survey. The GEE results showed a difference in the estimated mean of anxiety between the two groups, but the group × time interaction was not significant (p = .299). The anxiety of the intervention group, which was not statistically significant, decreased after the simulation-based training.

These results of the GEE analysis were consistent with those of the independent t-test. In the independent t-test, the differences before and after the intervention between the groups for the outcome variables showed significant changes in terms of knowledge (t = 10.35, $p < .001$), confidence (t = 5.52, $p < .001$), and preparedness (t = 7.10, $p < .001$), and insignificant difference in terms of anxiety (t = −0.39, p = .698) (See Supplementary Table 4).

Satisfaction and self-confidence in learning were measured only in the posttest in the intervention group (see Table 4). The degree of satisfaction for simulation-based education was high at an average of 23.62 ± 2.11. The item with the highest degree of satisfaction was: "the simulation provided me with a variety of learning materials and activities to promote my learning" at 4.86 ± 0.35. Self-confidence in learning was high at 36.22 ± 3.10, and the item with the highest score was: "my instructors used helpful resources to teach the simulation" at 4.84 ± 0.37.

Table 4. The Satisfaction and Self-Confidence in Learning of the Intervention Group after the Intervention (*N* = 37)

Variables	Mean ± SD	Range (reference)
Satisfaction with current learning	23.62 ± 2.11	18~25 (5~25)
Self-confidence in learning	36.22 ± 3.10	30~40 (8~40)

SD = Standard deviation.

DISCUSSION

This study developed and implemented simulation-based education in caring for the patients of COVID-19 for nursing students. It was based on the NLN Jeffries simulation theory, and its effectiveness was evaluated. Previous studies have not developed and evaluated theory-based simulation education for caring for the patients of COVID-19; they have mainly focused on educated healthcare workers donning and doffing PPE [31,34]. This study conducted simulation education using the scenario of caring for patients with common symptoms of COVID-19. As a result of measuring outcome variables using the NLN Jeffries simulation frameworks, the intervention group reported significant improvements in knowledge, confidence, and preparedness compared to the control group. Additionally, it reported a high-level of satisfaction and self-confidence in learning.

This is consistent with the result of an umbrella systematic review of simulation-based learning for nursing students [35], which showed that simulation experience improves students' knowledge, clinical skills, self-efficacy, and confidence. Simulation education, which facilitates active learning among students, is an effective educational method to improve knowledge compared to traditional lectures [36]. In particular, a study revealed that students who attend a pre-lecture of related content before participating in the simulation show significant improvements in their knowledge after the intervention compared to those who only receive simulation education [37]. This is supported in that the correct answer rate of COVID-19 knowledge was 78.0% in a study that did not conduct pre-lecture [38], while it was 96.0% in this study. Additionally, similar to a previous study that assessed COVID-19-related knowledge among emergency room nurses [24], the correct answer rate for isolation guidelines and sample management of subcategories was the lowest in the control group in this study, but high in the intervention group. Thus, simulation education and pre-lecture could be crucial in improving knowledge. Therefore, future studies should verify the significance of pre-lecture as a core requirement of nursing simulation education, further assessing long-term knowledge retention.

This study applied debriefing based on the GAS model after simulation. Decker et al. [39] reported that the debriefing session is an essential element in simulation-based learning to enhance learners' reflective thinking, and its integration into simulation education enhances learners' understanding, confidence, and skills. Similarly, in this study, the group that received simulation training including debriefing showed improvement in terms of confidence in performing infection control skills. Furthermore, the GAS model used as a structured framework for debriefing in this study can be applied to any debriefing situation, and help students assimilate easily [20]. As sufficient debriefing time is required for learners' skill improvement [40], debriefing was conducted for one hour in this study. Additionally, Waxman [41] proposed spending more than 2~3-times the scenario progress time as the debriefing time. As the optimal debriefing duration differs based on the purpose and type of simulation [39], it is necessary to allocate an appropriate debriefing time depending on each simulation situation in future studies.

Interestingly, this study educated participants in donning and doffing PPE prior to the simulation of nursing for the patients of COVID-19. According to a previous study [42] that confirmed the relationship between training and preparedness for nursing students, a high-level of training activity improves preparedness, and students who receive mechanical ventilation training along with PPE education feel a high-level of preparedness for nursing the patients of COVID-19. This supports our finding that the perception of preparedness in the intervention group was significantly improved compared to that in the control group. Additionally, Dharamsi et al. [43] emphasized the significance of in-situ simulation conducted in actual medical settings to improve learners' preparedness. However, there are limitations in conducting simulation education in the clinical setting for nursing students. Therefore, it can be a crucial factor in improving students' preparedness to implement high-fidelity simulation similar to clinical settings, through consultations with clinical professionals.

Conversely, anxiety was the variable that was analyzed as being insignificant in the verification of the intervention effect in this study. Although anxiety was reduced in the intervention group, the effect was not significant, which is consistent with the research result that students may feel anxiety because of various causes such as being observed during the simulation, especially being video recorded [44]. Similarly, Park & Kim [45] reported that students who received simulation education had a sense of responsibility for simulation implementation and experienced anxiety regarding poor learning outcomes. As a high-level of anxiety can interfere with learning and performance, it is reported that strategies such as maintaining psychological safety (i.e., a comfortable state without fear), conducting sufficient orientation to the simulation environment, and peer support are required to alleviate students' anxiety during simulation [44,46]. Therefore, in future research, it will be necessary to reinforce the following intervention strategies to effectively reduce anxiety among nursing students.

This study has a few limitations. First, as it used non-probability sampling, there could be the possibility of selection bias. Unfortunately, it was difficult to obtain cooperation from various institutions owing to the rapidly changing curriculum of universities due to the COVID-19 pandemic. This is also why we could not recruit more institutions for the intervention group. Therefore, it is necessary to minimize bias by conducting a randomized controlled trial in the future.

This study could be the Hawthorne effect because the researcher oversaw education and distribution of the online survey to the intervention group. Considering the intervention characteristics, it was difficult to conduct a blinded study because the contents of the educational program and variables being investigated were consistent, and the students recognized that the researcher was the instructor. This may have affected the survey score.

The tool measuring knowledge showed poor internal consistency. The reliability of the tool measuring the level of knowledge was lower than that in the developer's study [24]. This may have been caused by the differences in the survey method and the study participants. The developer's study [24] conducted written surveys targeted at nurses, whereas this study conducted online surveys targeted at nursing students. Additionally, as the level of knowledge in one item does not necessarily correlate with that of other items [47], the inconsistency in students' knowledge level during the pretest could have influenced the lower KR-20 value (similar to a previous study [48] that surveyed the knowledge of students). The posttest survey data in this study showed that the KR-20 coefficient was derived as .81. This suggests that the reliability was influenced by the participants' knowledge levels. In future studies, when there are differences in study participants and data collection methods from a previous study, it would be necessary to conduct a pre-evaluation of psychometric properties to ensure appropriate validity and reliability.

Finally, among the control group, sex and knowledge variables were not homogeneous in the baseline between the follow-up and the loss to follow-up groups. Based on a previous study [49], sex did not affect the difference of competence among nursing students in simulation education. Additionally, as the knowledge among the follow-up group was higher than among the lost to follow-up group, it may not have had a significant effect on the interpretation of the intervention results of this study. However, some of the characteristics between groups showed heterogeneity; therefore, it would be significant to minimize bias by reducing the dropout rate. The dropout rate in the control group was high, which was consistent with another study conducted online during the COVID-19 pandemic [50]. This might be because the participants in the control group were recruited voluntarily and did not have any in-person contact during the study period. However, the intervention group had in-person contact during the educational program. Future studies should consider this high dropout rate in the control group.

CONCLUSION

This study developed and applied simulation-based education for nursing the patients of COVID-19 based on the NLN Jeffries simulation theory, and evaluated its effectiveness. This simulation education improved students' knowledge, confidence in performing infection control skills, and perception of preparedness for caring for the patients of COVID-19, and they showed a high-level of satisfaction and self-confidence in learning. High-fidelity simulation, including pre-lecture, skill practice, debriefing, and reflective thinking activities enable nursing students develop the ability to care for the patients of COVID-19. This intervention will improve the quality of nursing care in future pandemics by improving the competency of prospective medical personnel, who play a crucial role in the healthcare system and society, further contributing to maintaining patient safety.

CONFLICTS OF INTEREST

The authors declared no conflicts of interest.

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DATA SHARING STATEMENT

Please contact the corresponding author for data availability.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.4040/jkan.22151.

AUTHOR CONTRIBUTIONS

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Data curation or/and Analysis: Lee MH & Noh EY.
Funding acquisition: Lee MH.
Investigation: Lee MH.

Project administration or/and Supervision: Lee MH.
Resources or/and Software: Noh EY.
Validation: Noh EY.
Visualization: Noh EY.
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