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Effects of Virtual Reality Cardiopulmonary Resuscitation Practice on the Knowledge, Skills, and Attitudes of Nursing Students: A single-blind randomized controlled trial (RCT)

Jui Kim[1], **Jung-Hee Song**[2], **Young-Ok Ha**[2]

[1]Assistant Professor, Department of Nursing, Ansan University, Ansan, Korea
[2]Associate Professor, Department of Nursing, Ansan University, Ansan, Korea

Purpose: This study aimed to assess the effects of virtual reality (VR) cardiopulmonary resuscitation (CPR)—as compared to those of face-to-face Basic Life Support (BLS) education—on nursing students' knowledge, skills, and attitudes.
Methods: Forty-four participants were recruited from nursing schools in Gyeonggi-do, Republic of Korea, and randomized into two groups: VR CPR (experimental group) and BLS (control group). The participants' CPR knowledge, cardiac compression quality, self-efficacy, confidence, and attitudes toward education were evaluated.
Results: At enrollment, the control and experimental groups showed similar results for all the variables. After the intervention, results showed that the cardiac compression score and the hand position accuracy in the experimental group were significantly higher than in the control group. Meanwhile, knowledge, self-efficacy, and confidence were improved in both groups, though there was no significant difference between the two groups.
Conclusion: The study results showed that VR CPR education is just as effective as face-to-face BLS training for nursing students. Therefore, developing high-quality VR educational content in the future is necessary.

Keywords: Virtual reality; Cardiopulmonary resuscitation; Education; Nursing students

Introduction

Cardiac arrest is the leading cause of acute in-hospital mortality in the world; the most important factor for determining the survival of patients with cardiac arrest is the presence of trained rescuers during the arrest situation [1]. Therefore, it is essential for nursing students to acquire the skills necessary for accurately detecting cardiac arrest, and these students, who are preparing to work in hospitals, should be able to respond quickly to the problem. The Basic Life Support (BLS) training program, an instructor-led, hands-on training program that is conducted in groups using training mannequins, is the most common method for transmitting basic cardiopulmonary resuscitation (CPR) training worldwide [2]. However, it has some challenges and drawbacks. The skills learned through BLS decline rapidly within six to nine months if CPR is not performed regularly [1]. Furthermore, the BLS educational method, in which a group gathers in one space and conducts face-to-face education with an instructor, had to be halted during the COVID-19 pandemic owing to restrictions on face-to-face gatherings.

Virtual reality (VR) is a technology that provides users with a realistic environment through real-time feedback in a virtual environment [3]. Currently, VR is being used across various fields because of its diverse advantages (e.g., high-quality training at a low cost and the capability to overcome temporal and spatial constraints) [4]. In the current post-pandemic situation, if basic

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Corresponding author: Young-Ok Ha
Department of Nursing, Ansan University, 155, Ansandaehak-ro, Sangnok-gu, Ansan-si, Gyeonggi, 15328, Korea
Tel: +82-31-400-7146 Fax: +82-31-400-7107 E-mail: yoha@ansan.ac.kr

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CPR and defibrillator education utilizing VR proves to have positive effects on nursing students' knowledge, skills, and attitudes, VR education may be regarded as a useful teaching method that can replace the existing BLS education.

VR education may provide useful knowledge that will help nurses improve the survival rates of patients requiring CPR. Specifically, nurses who have had VR CPR education may display the right skills for reducing the "no flow time" (i.e., the time from cardiac arrest to the initiation of CPR) by initiating immediate chest compressions [5]. Simultaneously, the quality of CPR for first-time witnesses has been highlighted as an important factor in its success [6,7]. Immediate chest compressions, the quality of chest compressions [8], and initial defibrillation quality [9] are important factors that influence patient prognosis in the case of cardiac arrest. However, thus far, no standardized VR education program has been developed for teaching CPR. Therefore, it is becoming more important to develop high-quality VR CPR education methods that will fit into the current virtual learning environment, and the importance of confirming the learning effects of VR CPR education programs has also been increasing.

To confirm the learning effects of VR CPR, two aspects are crucial: knowledge and technical aspects. Technical aspects include the technical ability to perform CPR immediately, the quality of heart compressions, and rapid defibrillation quality; these are complex but crucial factors for determining patient survival., Furthermore, learners' self-confidence and self-efficacy have a positive effect on the quality of learning outcomes. Nursing students must be confident in their ability to respond appropriately to patient emergencies [10]. Therefore, regarding the improvement of basic CPR performance quality among nursing students, relevant education is necessary for improving knowledge, technical aspects, and attitude aspects (e.g., the learner's self-confidence and self-efficacy). Given the variety of VR CPR training methods, this study not only examines the effectiveness of the specific VR CPR intervention used, but also investigates changes in attitudes, alongside the knowledge and skills [11,12] typically assessed in previous studies on VR CPR. This approach was taken to explore the potential for enhancing learning outcomes.

In this study, we examined the effects of VR CPR on nursing students' knowledge, skills, and attitudes. By confirming that there are no differences in its effects (e.g., learner efficacy and class immersion) compared to those of the existing traditional education method (BLS), we intend to use the results of the current study as basic data for improving current nursing practice.

This study aims to examine the effect of VR CPR on nursing students' CPR knowledge, skills, and attitudes, compared to traditional BLS training. The specific hypotheses for this study are as follows:

1) CPR-related knowledge and attitude scores will significantly increase before and after the VR CPR intervention.
2) There will be no significant difference in CPR-related knowledge, attitude, and skills between the VR CPR group and the BLS training group.

Methods

Study Design

The current study used a single-blind randomized controlled trial (RCT), which was conducted from June 20 to 24, 2022.

Participants

The study participants were students from the nursing department of a university in Gyeonggi-do, Republic of Korea. The inclusion criteria were as follows: aged over 20 years, had never been trained in a CPR course, could communicate without problems, understood the purpose of the study, and provided written informed consent to participate. Those who were unable to physically perform the functions necessary for CPR owing to physical constraints (e.g., pregnancy or certain joint problems) were excluded from the study. The sample size for this study was determined based on the results of a previous study [13], which analyzed changes in variables such as chest compression depth following VR intervention. Using the means and standard deviations reported in that study, the SWOG Statistical Center's statistical tools were employed to calculate the required sample size under a two-arm normal distribution with a two-sided test. This indicated that 34 participants would be required, and considering a dropout rate of approximately 30%, the target sample size was set at 44 participants.

Variables

1. Knowledge

1) Knowledge of CPR

The basic resuscitation preparation questions published on the Korean Association of Cardiopulmonary Resuscitation website were used in this study [14]. These comprise 10 multiple-choice questions about knowledge related to basic resuscitation. Each question is converted into a total score of 10 points (1 point each) on a scale of 0-10, with higher scores indicating higher knowledge.

2. Attitude

1) Learning self-efficacy

This study also used the learning self-efficacy measurement tool developed by Ayres [15] and adapted by Park and Kweon [16]. It comprises 10 questions assessed using a 5-point Likert scale, with a minimum of 10 points and a maximum of 50 points; higher scores indicate higher learning self-efficacy.

2) Confidence in nursing skills performance

Confidence in nursing skills performance was assessed by modifying the basic CPR and defibrillator application questions developed by the Korean Accreditation Board of Nursing Education [17]. It comprises 17 questions assessed using a 5-point Likert scale, with a minimum of 17 points and a maximum of 85 points; higher scores indicate higher performance.

3) Flow Short Scale in simulation

Regarding class engagement, the Short Flow Scale developed by Engeser and Rheinberg [18] was used in a modified form [19] as an assessment tool. It comprises 10 questions on a 5-point Likert scale, with a minimum of 10 points and a maximum of 50 points; higher scores indicate a higher level of immersion in class.

3. Skills

1) CPR-related skills

In this study, the cardiac compression score (points), depth of heart compression (mm), accuracy of chest compression depth (%), number of compressions per minute (numbers/min), Whether the chest compressions were performed at a precise rate of 100-120 per minute, relaxation rate of cardiac compression (%), and accuracy of hand positions (%) during chest compressions were measured using the Resusci Junior QCPR (Laerdal Medical, Norway) in accordance with the standards of the American Heart Association [20]. When the participants perform chest compressions using the Resusci Junior QCPR, it quantifies each participant's performance on the above variables and records them as numerical scores. In this study, the score values were used.

Experimental design

Before the intervention, all participants completed a survey online. The online questionnaire included general characteristics investigated in previous research examining the effects of VR CPR [12], such as gender, age, CPR experience, as well as assessments of knowledge of CPR, learning self-efficacy, and confidence in nursing skills performance of CPR. The experimental group practiced using the "CPR HEART" equipment developed by the DHC Wellness VR-AR Wellness Division of Daegu Health University in Korea. The CPR HEART comprises three scenarios (heart attack, drowning accident, and traffic accident), and its contents have been developed to train participants in the latest CPR (Basic Life Support) skills by using a fixed mannequin (Figure 1). The equipment comprised a VIVE PRO, VIVE tracker, chest compression input device (CPR mannequin), and a high-performance PC (Inteli7, GTX1070 or higher) (Figure 2). The scenario comprised stages, such as confirmation of the occurrence of the situation, confirmation of trauma to the subject, confirmation of consciousness, 119 calls, airway securing, CPR, defibrillator operation, and pad attachment. The participating students wore VR headsets and hand sensors and practiced according to the verbal and visual guidance provided by the program. The time required to complete each scenario comprised



Figure 1. VR CPR scenarios.



Figure 2. VR CPR demonstration.

10 minutes (Figure 2). Before the intervention, the experimental group was guided through the introduction of VR devices, operation methods, and precautions and instructed to stop the practice immediately if they experienced dizziness or motion sickness while wearing the head-mounted display. The research assistants worked together with the participants in the laboratory. Furthermore, after checking the VR CPR HEART practice video of an experienced teaching assistant, which had been filmed in advance, three participants formed a group to practice one scenario and to observe two scenarios. The time required for each group was 30 minutes.

The study's control group practiced the BLS skills. The BLS practice was led by a certified instructor. After hearing the steps and scenarios for CPR, three to four participants shared a mannequin during practice and were evaluated after the practice. The BLS practice lasted for approximately 4 hours. After the experimental and control groups practiced CPR, a postmortem survey was conducted to investigate their basic CPR knowledge, performance confidence, learning self-efficacy, and class immersion. Laerdal's Resusci Junior QCPR was used to investigate the depth, speed, and relaxation rate of the heart compressions; hand positions and heart pressure scores were also measured. The entire process of the experiment can be summarized as shown in Figure 3.

Statistical Analysis

The program was evaluated using SPSS/WIN version 26.0 (SPSS Inc., Chicago, IL, USA). Differences were considered statistically significant at $p < 0.05$. Independent t-test and $\chi 2$-test were used to compare the baseline characteristics between the experimental and control groups at the beginning of the study. Prior to conducting the independent t-test, normality tests were performed using the Shapiro-Wilk test for the variables of interest. Since the normality assumption was satisfied ($p > 0.05$), the independent t-test was carried out. To compare the means of the variables (knowledge of CPR, confidence in nursing skills performance, and learning self-efficacy) within the groups in the period from pre- to post-intervention, a paired t-test was used. Furthermore, an independent t-test was used before and after the intervention to compare the mean differences in the variables (knowledge of CPR, confidence in nursing skills performance, and learning self-efficacy) between the groups. To compare the means of the variables (cardiac compression depth and rate) between the groups after the intervention, an independent t-test was used.

Ethical considerations

The study protocol was approved by the Ansan University ethics committee (No. 2022-06-002). All procedures performed in studies involving human participants were in accordance with

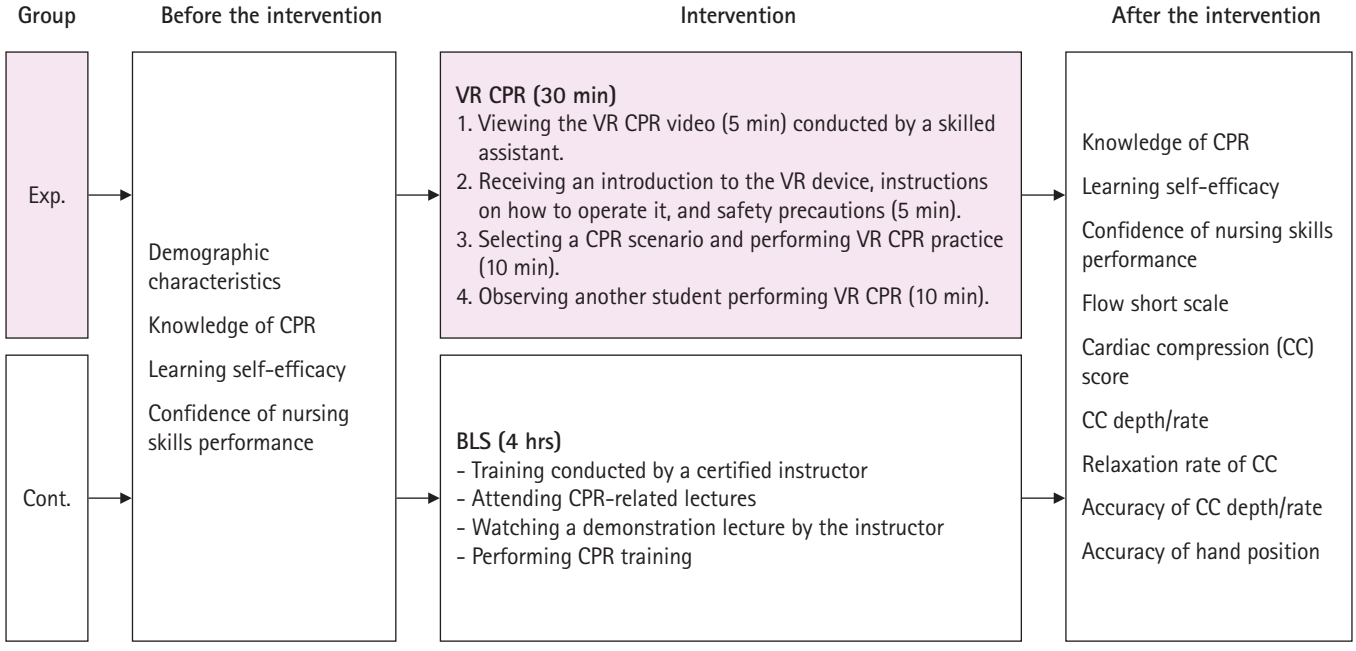

Figure 3. The entire process of the experiment.

the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The participants in this study were nursing university students, and therefore, the following ethical considerations were made for the experiment. Before the study, participants were informed that their decision to participate would not affect their academic performance in any way. During the study, participants did not have direct interaction with the professors, and the intervention was carried out by trained researchers. The trained researchers coded the participants' data and transferred it to the professor responsible for analysis. Data analysis was performed by a professor who had not taught the study participants.

Results

Participants' characteristics and baseline comparison

The demographic data of the 44 students enrolled in this study are presented in Table 1. For this study, 23 and 21 participants were randomized into the experimental and control groups, respectively. There were no statistically significant differences in the distribution of descriptive student characteristics between the experimental and control groups ($p > 0.05$) (Table 1).

Hypothesis testing

Hypothesis 1: CPR-related knowledge and attitude scores will significantly increase before and after the VR CPR intervention.

The VR CPR group showed a significant improvement in CPR knowledge scores from baseline (6.08 ± 1.27) to post-intervention (6.87 ± 0.91) (t = -2.44, $p = .023$). Learning Self-Efficacy: Self-efficacy scores also improved significantly in the VR CPR group, rising from 43.00 ± 5.54 at baseline to 47.47 ± 5.19 post-intervention (t = -4.55, $p < .001$). Confidence in Nursing Skills: The VR CPR group exhibited a significant increase in confidence in nursing skills performance, with scores increasing from 61.13 ± 11.47 to 74.78 ± 8.39 after the intervention (t = -6.23, $p < .001$) (Table 2).

Hypothesis 2: There will be no significant difference in CPR-related knowledge, attitude, and skills between the VR CPR group and the BLS training group.

No significant difference was found between the VR CPR group (6.87 ± 0.91) and the BLS group (7.14 ± 1.31) in CPR knowledge scores after the intervention (t = 0.10, $p = .921$). Both groups demonstrated comparable improvements in learning self-efficacy scores, with no statistically significant difference between the VR CPR and BLS groups (t = 0.82, $p = .419$). Post-intervention confidence scores in nursing skills performance were not significantly different between the VR CPR group and the BLS group (t = -1.73, $p = .091$). The Flow Short Scale assessed the participants' engagement and experience during the interventions. Post-intervention results revealed a higher, though not statistically significant, average flow score in the control group (47.09 ± 4.65) compared to the experimental group (44.30 ± 5.37), with t = -1.83 and $p = .074$ (Table 2).

The VR CPR group had a significantly higher cardiac compression score (83.95 ± 13.99) than the BLS group (63.23 ± 41.31), indicating an advantage for VR training (t = 2.19, $p = .039$). The mean depth of cardiac compressions in the VR CPR group was 51.00 ± 4.18 mm, compared to 47.76 ± 6.37 mm in the BLS group. This difference was marginally significant (t = 2.01, $p = .051$). Compression rates were maintained within the recommended range for both groups, with the VR CPR group averaging 115.26 ± 13.37 compressions per minute and the control group 110.19 ± 7.90 compressions per minute, showing no significant

Table 1. Baseline Demographic Characteristics (N=44)

Variables	Categories or score	Experimental (n = 23)	Control (n = 21)	χ^2/t	p
		n (%) or Mean ± SD			
Gender, n %	male	1 (4.3)	5 (23.8)	3.53	.088
	female	22 (95.7)	16 (76.2)		
Age (years)		23.17 ± 1.40	23.52 ± 2.60	-0.55	.588
CPR experience, n %	yes	0 (0.0)	1 (4.8)	1.12	.477
	no	23 (100.0)	20 (95.2)		
Satisfaction with nursing studies	1-5	4.21 ± 0.95	3.95 ± 0.86	0.96	.341
Knowledge of CPR (points)	0-10	6.08 ± 1.27	6.04 ± 1.32	0.10	.921
Learning self-efficacy (points)	10-50	43.00 ± 5.54	41.47 ± 6.82	0.82	.419
Confidence in nursing skills performance (points)	17-85	61.13 ± 11.47	67.04 ± 11.19	-1.73	.091

Table 2. Results of CPR-related Knowledge and Attitude Scores for the Experimental and Control Groups at Baseline and after the Intervention (*N*=44)

Variables		Group	Baseline	After the intervention	t	*p*	Differences	t	*p*
			Mean ± SD				Mean ± SD		
Knowledge	Knowledge of CPR	exp.	6.08 ± 1.27	6.87 ± 0.91	-2.44	.023	0.78 ± 1.53	0.10	.921
		cont.	6.04 ± 1.32	7.14 ± 1.31	-2.90	.009	1.09 ± 1.72		
Attitude	Learning self-efficacy	exp.	43.00 ± 5.54	47.47 ± 5.19	-4.55	< .001	4.47 ± 4.71	0.82	.419
		cont.	41.47 ± 6.82	47.28 ± 4.44	-4.39	< .001	5.80 ± 6.07		
	Confidence in nursing skills performance	exp.	61.13 ± 11.47	74.78 ± 8.39	-6.23	< .001	13.65 ± 10.51	-1.73	.091
		cont.	67.04 ± 11.19	79.76 ± 6.93	-6.05	< .001	12.71 ± 9.62		
	Flow short scale	exp.		44.30 ± 5.37				-1.83	.074
		cont.		47.09 ± 4.65					

Table 3. Results of CPR-related Skills Scores for the Experimental and Control Groups after the Intervention (*N*=44)

Variables		Group	n (%) or Mean ± SD	χ^2 /t	*p*
Skills	Cardiac compression score (points)	exp.	83.95 ± 13.99	2.19	.039
		cont.	63.23 ± 41.31		
	Cardiac compression depth (mm)	exp.	51.00 ± 4.18	2.01	.051
		cont.	47.76 ± 6.37		
	Cardiac compression numbers per min (numbers/min)	exp.	115.26 ± 13.37	1.55	.131
		cont.	110.19 ± 7.90		
	Relaxation rate of cardiac compression (%)	exp.	81.69 ± 28.06	-0.73	.467
		cont.	87.57 ± 24.75		
	Accuracy of cardiac compression depth (%)	exp.	63.37 ± 38.25	1.21	.234
		cont.	48.85 ± 41.55		
	Accuracy of cardiac compression numbers per min, 100-120/min, n (%)	exp.	12 (52.2)	4.05	.060
		cont.	17 (81.0)		
	Accuracy of hand position (%)	exp.	99.73 ± 1.25	2.42	.025
		cont.	78.71 ± 39.75		

difference between the groups ($\chi^2 = 1.55$, $p = .131$).

The relaxation rate, which measures the extent of recoil allowed during compressions, was similar between groups, with the VR CPR group scoring 81.69 ± 28.06% and the control group 87.57 ± 24.75%, and no significant difference was observed ($\chi^2 = -0.73$, $p = .467$). Additionally, the accuracy of achieving the recommended compression depth was higher in the VR CPR group (63.37 ± 38.25%) than in the control group (48.85 ± 41.55%), though this difference was not statistically significant ($\chi^2 = 1.21$, $p = .234$). When examining the accuracy of the compression rate, 52.2% of participants in the VR CPR group achieved a rate within the target range of 100-120 compressions per minute, compared to 81.0% in the control group, which approached significance but was not statistically conclusive ($\chi^2 = 4.05$, $p = .060$).

Notably, the accuracy of hand position was significantly higher in the VR CPR group, with a score of 99.73 ± 1.25% compared to 78.71 ± 39.75% in the control group, marking a statistically significant advantage for VR training ($\chi^2 = 2.42$, $p = .025$). These findings suggest that while both VR CPR and BLS training were effective in enhancing CPR-related skills, the VR CPR training provided notable advantages in specific skill areas, particularly in compression quality and hand positioning accuracy (Table 3).

Discussion

This study confirmed that VR CPR is as effective as face-to-face CPR education for improving nursing students' knowledge, skills, and attitudes. The results showed that knowledge of CPR, learning self-efficacy, and confidence in nursing skills performance significantly improved after the intervention in both groups, compared to before the intervention. These results support hypothesis 1, showing that VR CPR training effectively improved CPR knowledge and attitude in the experimental group.

The results of this study indicated that there were no significant differences between the experimental group and control group in terms of knowledge of CPR learning self-efficacy, confidence in nursing skills performance, and flow short scale. These findings confirm hypothesis 2 with regard to knowledge and attitude, showing that both VR and traditional BLS training led to similar gains in CPR-related knowledge, and attitudes. In hypothesis 2, we expected that there would be no significant difference in CPR skills between the experimental and control groups. However, the results of this study showed that the experimental group had significantly higher cardiac compression scores and accuracy of hand position compared to the control group.

The current study showed that nursing students' confidence and self-efficacy in CPR increased significantly after they were exposed to the VR CPR intervention; this outcome is similar to that of previous studies [11,21]. Both groups experienced a significant increase in CPR knowledge after the intervention without any significant inter-group differences. This finding is consistent with the results of a previous study [13], thus indicating that both the traditional education method and VR CPR training can improve nursing students' knowledge as well as their confidence and efficacy. CPR trainees should be aware of the correct procedure, as the reduction of the "no flow time" is critical for patient's survival in CPR situations [5]. In this regard, the results of this study confirm that VR CPR is an educational method that helps participants recognize procedures as accurately as traditional BLS training.

This study found no significant differences in chest compression depth and chest compression rate between the experimental and control groups. Some past studies showed that VR CPR training had a similar cardiac compression rate compared to that of face-to-face training, but the depth of cardiac compression was insufficient in VR CPR training [12]. Other studies reported no significant difference in terms of cardiac compression rates and depth between the existing traditional method and the VR training method [21,22]. Thus, the results regarding cardiac compression depth and rate show variability across different studies.

In this study, no significant difference in chest compression depth was observed between the experimental and control groups. However, the experimental group performed compressions greater than 5 cm, in accordance with the standards of the American Heart Association [20], while the control group applied compressions of 4.8 cm. Additionally, the accuracy of hand position during chest compressions was significantly higher in the experimental group compared to the control group. Consequently, the total cardiac compression score (i.e., measuring the accuracy of depth, number of chest compressions, points reflecting hand positions, and relaxation rate) was significantly higher in the experimental group than in the control group. The observed results may have been influenced by the specific differences in the instructional methods employed in this study, as well as the variability in the VR content utilized. The VR CPR approach implemented in our research was designed to provide immediate, corrective feedback whenever learners failed to perform chest compressions at the recommended speed or depth, or when hand positioning was inaccurate. It is hypothesized that this feedback-driven VR CPR training method played a crucial role in enhancing the quality of chest compressions.

This study had some limitations. First, this current study's method was planned as an RCT in order to secure the participants' homogeneity; however, the chest compression quality performance score was not evaluated before the intervention. Therefore, it is possible that the homogeneity of this part was not clearly secured. Second, the study design could not completely exclude the halo effect from this single-blind study. Third, the current study results cannot be generalized because of the limited number of study participants. However, despite these limitations, this study demonstrated that VR CPR training was as effective as existing face-to-face BLS training in terms of improving nursing students' CPR knowledge, skills, and attitudes. However, because VR CPR can have various results with regard to maintaining the quality of cardiac compressions depending on contents and educational methods, it can be concluded that, if VR is used in the CPR course curriculum, greater emphasis should be placed on applying a more effective teaching method.

Conclusions

This study was conducted to confirm that VR CPR is as effective as existing face-to-face BLS education for teaching knowledge, skills, and attitudes to nursing students. The results showed that VR CPR improved their knowledge of CPR, learning self-efficacy, and confidence in nursing skills performance. Furthermore, the VR CPR group showed significantly higher cardiac compression scores and accuracy. These results confirmed that VR CPR is an effective educational method for teaching CPR. To increase the effectiveness of VR CPR, it is important to apply suitable educational methods among learners and utilize appropriate contents and teaching methods.

Future studies should include participants from different backgrounds and a larger research sample. Furthermore, future studies should include efforts to confirm the difference by teaching

methods through VR CPR. Finally, we propose that a repeated-measurement study could examine the durability of VR CPR effects.

ORCID

Jui Kim, https://orcid.org/0000-0001-8450-8087
Jung-Hee Song, https://orcid.org/0000-0002-0415-3827
Young-Ok Ha, https://orcid.org/0000-0002-6168-2047

Conflict of interest

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Authors' contributions

Jui Kim contributed to conceptualization, data curation, formal analysis, methodology, writing - original draft, review & editing, resources, supervision, and validation. Jung-Hee Song contributed to conceptualization, data curation, methodology, visualization, and writing - original draft. Young-Ok Ha contributed to conceptualization, formal analysis, methodology, writing - original draft, review & editing, and supervision.

Data availability

Please contact the corresponding author for data availability.

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