ORIGINAL ARTICLE

Effects of the non-contact cardiopulmonary resuscitation training using smart technology

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Aims	Accurate cardiopulmonary resuscitation (CPR) performance is an essential skill for nursing students so they need to learn the skill correctly from the beginning and carry that forward with them into their clinical practice. For the new normal after coronavirus disease 2019 (COVID-19), safe training modules should be developed. This study aimed to develop non-contact CPR training using smart technology for nursing students and to examine its effects, focusing on the accuracy of their performance. The study used a prospective, single-blind, randomized, and controlled trial with repeated measures.
Methods and results	The non-contact CPR training with smart technology consisted of a 40-min theoretical online lecture session and an 80-min non-contact practice session with real-time feedback devices and monitoring cameras. Sixty-four nursing students were randomly assigned to either an experimental group ($n = 31$) using non-contact training or a control group ($n = 33$) using general training. The accuracy of chest compression and mouth-to-mouth ventilation, and overall performance ability were measured at pretest, right after training, and at a 4-week post-test. The non-contact CPR training significantly increased the accuracy of chest compression ($F = 63.57$, $P < 0.001$) and mouth-to-mouth ventilation ($F = 33.83$, $P < 0.001$), and the overall performance ability ($F = 35.98$, $P < 0.001$) compared to the general CPR training over time.
Conclusions	The non-contact CPR training using smart technology help nursing students develop their techniques by self-adjusting compression depth, rate, release and hand position, and ventilation volume and rate in real time. Nursing students can learn CPR correctly through the training allowing real-time correction in safe learning environments without face-to-face contact.
Keywords	Cardiopulmonary resuscitation • Quality improvement • Training • Technology

Implications for practice

- For the new normal after Coronavirus Disease 2019 (COVID-19) safe training modules should be developed.
- The non-contact training using smart technology help students develop their techniques by self-adjusting compression depth, rate, release and hand position, and mouth-to-mouth ventilation volume and rate in real time.
- Nursing students can learn CPR correctly through the training allowing real-time correction in safe learning environments without face-to-face contact.
- The non-contact training using smart devices as well as monitoring cameras can be applied as a safe education module for the new normal after COVID-19.

Introduction

As the coronavirus disease (COVID-19) pandemic requires social distancing and quarantine, face-to-face educational practices in school have been prohibited. For the new normal after COVID-19 various non-contact training modules using safe technology should be developed for safe education. The cardiopulmonary resuscitation (CPR) training is one of the most important for nursing students to learn prompt and accurate skills. The 2015 CPR guidelines suggest conducting CPR training focusing on the accuracy of the CPR performance such as compression depth and adequate ventilation, because the survival rate and complications are associated with its accuracy.[1,2] The 2019 focused updates to the guidelines for CPR also highlighted the importance of ventilation as well as chest compression.[3,4]

The quality of CPR performance consists of accurate chest compression rate and depth, full chest recoil between compressions, minimizing interruptions in chest compression, and avoiding excessive ventilation.[5] The guideline of high-quality CPR recommends a chest compression depth of approximately 5 cm, complete chest recoil, a chest compression rate of 100 to 120/min, minimizing the hold time of the chest compression to less than 10 s, and avoiding excessive breathing in mouth-to-mouth ventilation.[1] Complications caused by the inaccurate CPR performance are rib fractures, sternal fractures, pericardial and pleural haemorrhages, internal organ injuries, and pulmonary hyperdilation.[6,7]

To increase the survival rate of cardiac arrest cases, many buildings such as apartments and subway stations are legally required to install an automated external defibrillator (AED) box.[8] Many nursing schools train CPR with an AED for people suffering cardiac arrest on the street with various training methods. The CPR training includes the smart devices to improve the quality of performance such as a real-time personal computer skill-reporting system.[9,10] Currently non-contact training methods such as virtual simulation and remote health training are in the spotlight. However, little is known about the effects of non-contact CPR training using smart technology in nursing students. Therefore, this study was conducted to develop a non-contact CPR education module focusing on the accuracy of performance.

The purpose of this study was to develop the non-contact CPR training for nursing students using smart technology displaying the detailed degrees of performance accuracy in real-time to adjust their skills during performance training, and to test its effects on the accuracy of chest compression and mouth-to-mouth ventilation, and the overall performance abilities.

Methods

Study design

The study employed a prospective, single-blind, randomized, and controlled trial with repeated measures with nursing students.

Participants

The study participants were 64 junior nursing students from a university in South Korea, and they were randomly assigned into the experimental group (*n* = 31) and the control group (*n* = 33). Inclusion criteria were (i) nursing students who had completed the theoretical courses on cardiopulmonary anatomy as well as nursing care for persons with cardiopulmonary diseases and (ii) those students who are about to start clinical practice. Exclusion criteria were (i) students with basic life support (BLS) certifications and (ii) students completed or taking any BLS trainings using any real-time feedback devices.

The sample size was calculated as 62 using G*Power 3.1.2 sample calculation program[11] with a significance level of 0.05, power of 80%, and effect size of 0.30 based on a previous study for two-way repeated-measures ANOVA.[12] Anticipating an attrition rate, 70 nursing students were recruited. During the procedure, two students dropped out due to the scheduling difficulties before the practice session and four students dropped out at the 4 weeks post-test because of their course examinations (*Figure 1*). *Post hoc* power was calculated as 99.9% in this study.

Intervention

The experimental group intervention

The contents of the non-contact CPR training using smart technology were developed through a literature review and focus group interviews (*Figure 2*). The literature review included 19 research articles, and five sets of guidelines published within the past 10 years sourced from search engines using the search terms of 'cardiopulmonary resuscitation', 'feedback device', or 'smart technology'. The focus group interviews were conducted with an expert panel including two nursing professors, two physicians, and five basic life support (BLS) instructors. The optimal goal of the education module was for self-directed repeated learning. The learning objectives of the training were to understand the algorithm of basic CPR and to self-directed practice CPR with smart technology. The scenario includes the case where a person is found who has suddenly fallen down at a subway station.

The training consisted of a 40-min theoretical online lecture session and an 80-min non-contact practice session. The contents of two sessions covered (i) the CPR process, (ii) assessment, (iii) chest compression, (iv) mouth-to-mouth ventilation, (v) using the AED, and (vi) reassessment. The 80-min non-contact CPR practice training used the real-time on-screen feedback devices (SkillGuide from Laerdal Medical) displaying the detailed degrees of compression depth, complete or incomplete release, compression rate, time, and hand placement continuously during the CPR performance. It allowed the students to identify accurate chest compression and mouth-to-mouth ventilation in real time and to adjust their strength and skills. A training nurse guided the practice in the control room. A training nurse can observe the student directly through a glass window, grasp facial expressions and detailed movements through two cameras, identify the accuracy of a student's CPR practice in real time through a monitor linked to a smart device, and educate the student on the CPR process and give feedback through a microphone. After completing each CPR performance, the debriefing session allowed students to recognize their overall performance and the degrees of performance accuracy from the visual records of proximity and distance cameras as well as the debrief mode records of the real-time devices. The content validity index (CVI) was calculated from the expert panel as 0.95.

The control group intervention

The general CPR training consists of the 40-min theoretical online lecture session as the same as the experimental group and the 80-min face-to-face practice session with a training nurse covering the same contents of (i) CPR process, (ii) assessment, (iii) chest compression, (iv) mouth-to-mouth ventilation, (v) AED, and (vi) reassessment, but without real-time feedback from the smart devices. A training nurse observed and guided students' performance and provided feedback through face-to-face education. After completing each CPR performance, the students reviewed the details of their overall performance from the records of proximity
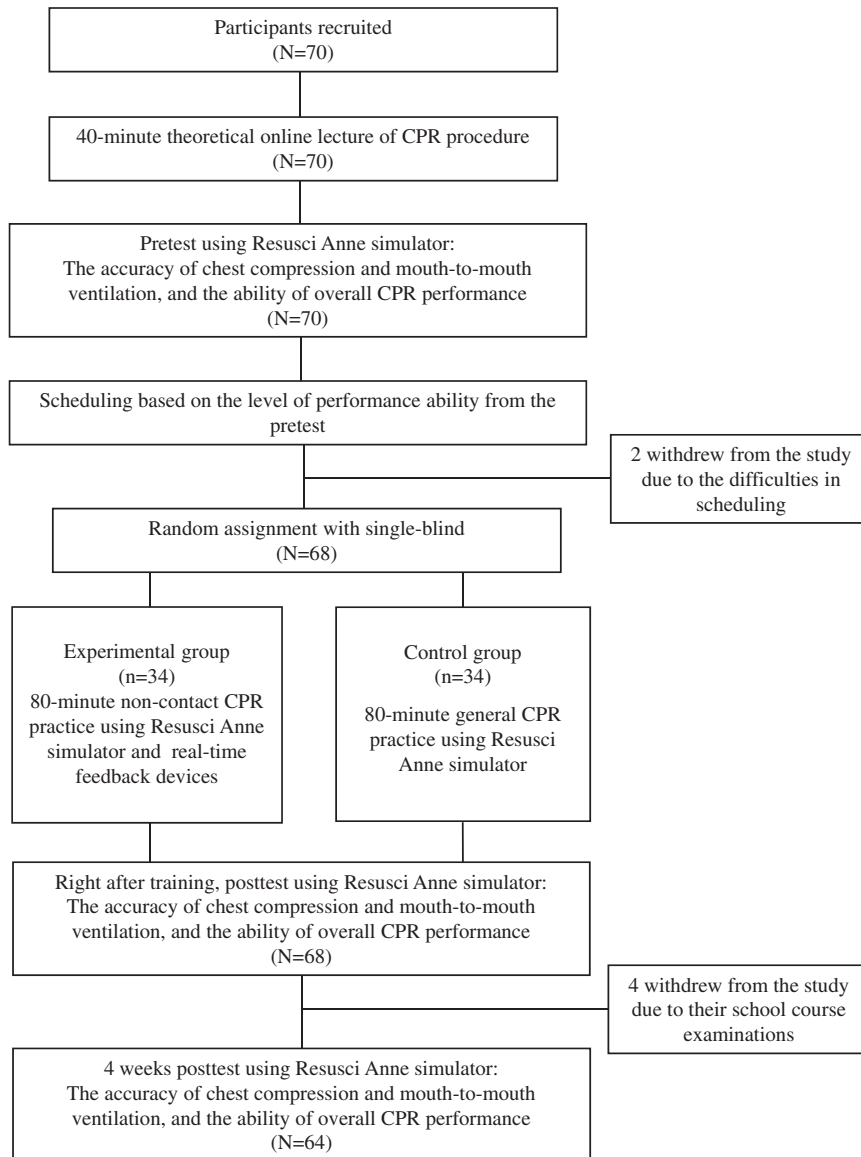
Figure 1 Research progress flowchart.

and distance cameras in the debriefing session. The content validity index (CVI) of the training was calculated from the expert panel as 0.92.

Measurements

Chest compression accuracy
Chest compression accuracy was assessed with the chest compression scores from the debriefing mode of the smart device. The scores are calculated from compression depth, rate, release, and hand position. The total scores range from 0 to 100 and higher scores are associated with enhanced accuracy of chest compression. The intra-class correlation coefficient of this instrument was 0.92 among instructors in this study.

Mouth-to-mouth ventilation accuracy
Mouth-to-mouth ventilation accuracy was assessed with the mouth-to-mouth ventilation scores from the debriefing mode of the smart device ranging from 0 to 100. The rescue breath scores are calculated from

breathing volume and rate. Higher scores are associated with enhanced accuracy of mouth-to-mouth ventilation. The intra-class correlation coefficient of this instrument was 0.89 among instructors in this study.

CPR performance ability
Cardiopulmonary resuscitation performance ability was measured using the 20-item CPR performance ability scale based on the 2015 Korean guideline for CPR[13] which is widely used in general CPR trainings. The scale consists of a check for response (1 item), shout for help (2 items), check for pulse and breathing (2 items), chest compression (7 items), mouth-to-mouth ventilation (3 item), use the AED (4 items), and recheck for pulse (1 item). It used a three-point scale with zero = 'poor', one = 'good', and two = 'excellent'. Higher scores mean the greater ability of CPR performance. Two measurement researchers rated students using the scale and recheck the items based on the visual data recorded by
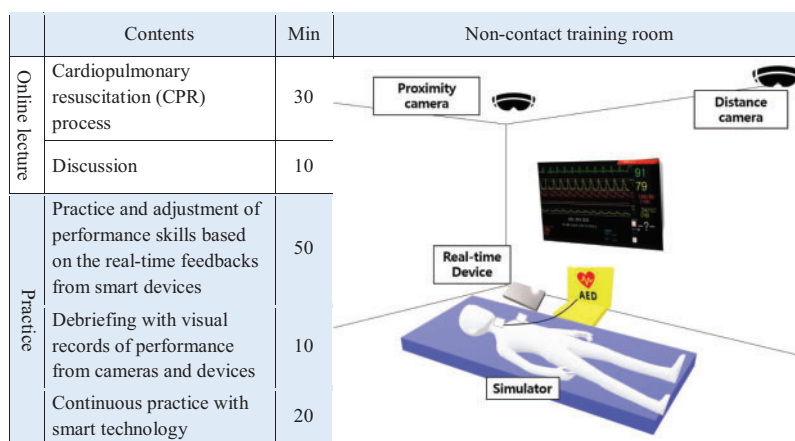
	Contents	Min	Non-contact training room
Online lecture	Cardiopulmonary resuscitation (CPR) process	30	
	Discussion	10	
Practice	Practice and adjustment of performance skills based on the real-time feedbacks from smart devices	50	
	Debriefing with visual records of performance from cameras and devices	10	
	Continuous practice with smart technology	20	

Figure 2 The non-contact cardiopulmonary resuscitation training.

multiple monitoring cameras and the mean scores were used in the analysis. The Cronbach's α was 0.93, and Kappa was 0.74 in this study.

Study procedure

Study flyers were posted on the student bulletin boards at the school of nursing. Participants who met the criteria were recruited and given the study explanation. Whenever 12 participants were recruited, the 40-min theoretical online lecture was conducted and then the pretest was carried out. The measurement researchers conducted the pretest including the accuracy and abilities of CPR performance with Resusci Anne simulator, and general characteristics. The accuracy scores of CPR performance were extracted from the smart device records, and the overall CPR performance abilities were measured by two measurement researchers. The measurement researchers rechecked the overall CPR performance abilities based on the visual data recorded from two cameras (proximity and distance). Considering the scores of the pretest, we set up the schedules by pairing two students with similar levels.

On the day of the 80-min CPR practice training, the mates were randomly assigned to experimental and control groups by coin flipping, but they did not know whether they were in the experimental or control group. The 80-min training was conducted by two training nurses. One nurse for the experimental group guided practice in the control room and the other for the control group did face-to-face. Posttest was conducted by two measurement researchers at right after the training and 4 weeks later to identify the continuity of the training effects. Data were collected from 13 June 2016 to 9 June 2017.

Ethical consideration

The study complies with the Declaration of Helsinki. The study was conducted after the institutional review board (IRB) approval of Kyung Hee University (KHSIRB-16-018NA). All of the participants voluntarily submitted informed consents after getting the study explanation from the researchers. The informed consents included human rights of self-determination, privacy, confidentiality, and fair treatment along with the study purpose and process. All data were treated anonymously with a study identification number.

Data analysis

The collected data were analysed with IBM SPSS Statistics 24 for Window (IBM Corporation, Armonk, NY, USA). Tests for normality were conducted using Kolmogorov–Smirnov before the parametric statistics and revealed the normal distributions of the continuous variables. The study variables were compared using Fisher's exact test, χ^2-test, independent sample *t*-test, and two-way repeated-measures ANOVA. The reliability of the instruments was tested by Cronbach's α, Kappa, and intra-class correlation coefficient. The validity of the training contents for both groups was measured by CVI.

Results

The majority of the participants were females, and the mean age was 21.26 ± 0.68 for the experimental group and 21.27 ± 0.94 for the control group. There were no significant differences in gender, age, the experience of CPR education, and study variables between the two groups (*Table 1*).

Effects of the non-contact CPR training on the accuracy of chest compression and mouth-to-mouth ventilation

The scores of chest compression accuracy in the experimental group increased from 52.06 before training to 92.65 right after training and slightly decreased to 90.39 4 weeks later while those of the control group improved increased from 52.27 to 75.61 and decreased to 66.06. Two-way repeated measures ANOVA showed significant a time and group interaction ($F = 63.57$, $P < 0.001$), an effect of time ($F = 379.94$, $P < 0.001$), and a difference between the two groups that was statistically significant ($F = 45.02$, $P < 0.001$).

The scores of mouth-to-mouth ventilation in the experimental group increased from 48.81 at baseline to 89.10 at right after and slightly decreased to 85.26 at 4 weeks later while the control group improved from 49.27 to 78.85, and 70.58. Repeated measures analysis showed significant a time and group interaction ($F = 33.83$, $P < 0.001$), an effect of time ($F = 326.05$, $P < 0.001$), and a difference between the two groups that was statistically significant ($F = 12.54$, $P = 0.001$) (*Table 2, Figure 3*).

Table 1 Homogeneity test of experimental and control groups (N = 64)

Characteristics	Categories	Exp. (n = 31) n (%) or M ± SD	Cont. (n = 33) n (%) or M ± SD	Fisher's, χ^2 or t	P
Gender	Male	3 (9.7)	1 (3.0)		0.347
	Female	28 (90.3)	32 (97.0)		
Age (years)		21.26 ± 0.68	21.27±.94	-0.07	0.944
Experience of CPR training	None	7 (22.6)	10 (30.3)	0.50	0.779
	Lecture	16 (51.6)	15 (45.5)		
	Lecture and practice	8 (25.8)	8 (24.2)		
Chest compression		52.06 ± 9.22	52.27 ± 10.73	-0.08	0.934
Mouth-to-mouth ventilation		48.81 ± 10.21	49.27 ± 12.12	-0.17	0.869
Overall CPR performance		23.10 ± 5.91	23.61 ± 6.58	-0.33	0.746

Cont., control group, CPR, cardiopulmonary resuscitation; Exp., experimental group.

Table 2 Study variables at pretest, right after, and 4 weeks post-test (N = 64)

Variable	Measures	Exp. (n = 31) M ± SD	Cont. (n = 33) M ± SD	Source	F	P	LSD
Accuracy of chest compression	Baseline[a]	52.06 ± 9.22	52.27 ± 10.73	Group	45.02	<0.001	a < c<b
	Right after[b]	92.65 ± 7.66	75.61 ± 11.31	Time	379.94	<0.001	
	4 weeks[c]	90.39 ± 5.97	66.06 ± 10.03	Group*Time	63.57	<0.001	
Accuracy of mouth-to-mouth ventilation	Baseline[a]	48.81 ± 10.21	49.27 ± 12.12	Group	12.54	0.001	a < c<b
	Right after[b]	89.10 ± 10.87	78.85 ± 11.94	Time	326.05	<0.001	
	4 weeks[c]	85.26 ± 8.41	70.58 ± 8.77	Group*Time	33.83	<0.001	
Ability of CPR performance	Baseline[a]	23.10 ± 5.91	23.61 ± 6.58	Group	8.17	0.006	a < c<b
	Right after[b]	37.23 ± 3.95	33.06 ± 4.87	Time	430.19	<0.001	
	4 weeks[c]	34.87 ± 4.30	27.97 ± 5.25	Group*Time	35.98	<0.001	

Cont., control group; CPR, cardiopulmonary resuscitation; Exp., experimental group.

Effects of the non-contact CPR training on the performance abilities

The scores of the CPR performance abilities in the experimental group increased from 23.10 at baseline to 37.23 at right after the training and slightly decreased to 34.87 at 4 weeks later while the control group improved from 23.61 to 33.06, and then decreased to 27.97. Repeated measures analysis showed significant a time and group interaction (F = 35.98, P < 0.001), an effect of time (F = 430.19, P < 0.001), and a difference between the two groups that was statistically significant (F = 8.17, P = 0.006) (*Table 2, Figure 3*).

Discussion

The accuracy of CPR performance is closely associated with a survival rate as well as preventing complications.[14,15] However, due to COVID-19, only non-contact education is allowed as a safe education instead of face-to-face education. This study developed the non-contact CPR training using smart technology for nursing students to increase the accuracy of their performance and examined its effects with repeated measures. The smart devices displayed the real-time

degrees of chest compression depth, complete or incomplete release, compression rate, time, and correct hand placement, which allowed students to adjust their strength and skills during the CPR performance. The devices also summarized the details of patient conditions right after completing the performance. This training provides the advantage that students can continuously check the accuracy of their performances and adjust the appropriate compression position, depth, intensity, and rescue breath in real time for themselves without face-to-face contact.

Improving the CPR performance quality, in terms of accuracy, is one of the most significant goals in resuscitation practice.[16] The non-contact training using smart technology increased the scores of the accuracy in chest compression by 40.59 points from baseline to right after the training and slightly decreased by 2.26 at 4 weeks later in the experimental group compared to the control group increased by 23.34 points and then decreased by 9.55. On the other hand, the accuracy scores of mouth-to-mouth ventilation increased by 40.29 points from baseline to right after the training and decreased by 3.84 at 4 weeks in the experimental group compared to the control group increased by 29.58 points and then decreased by 8.27. That is, the non-contact training using smart technology was more effective for
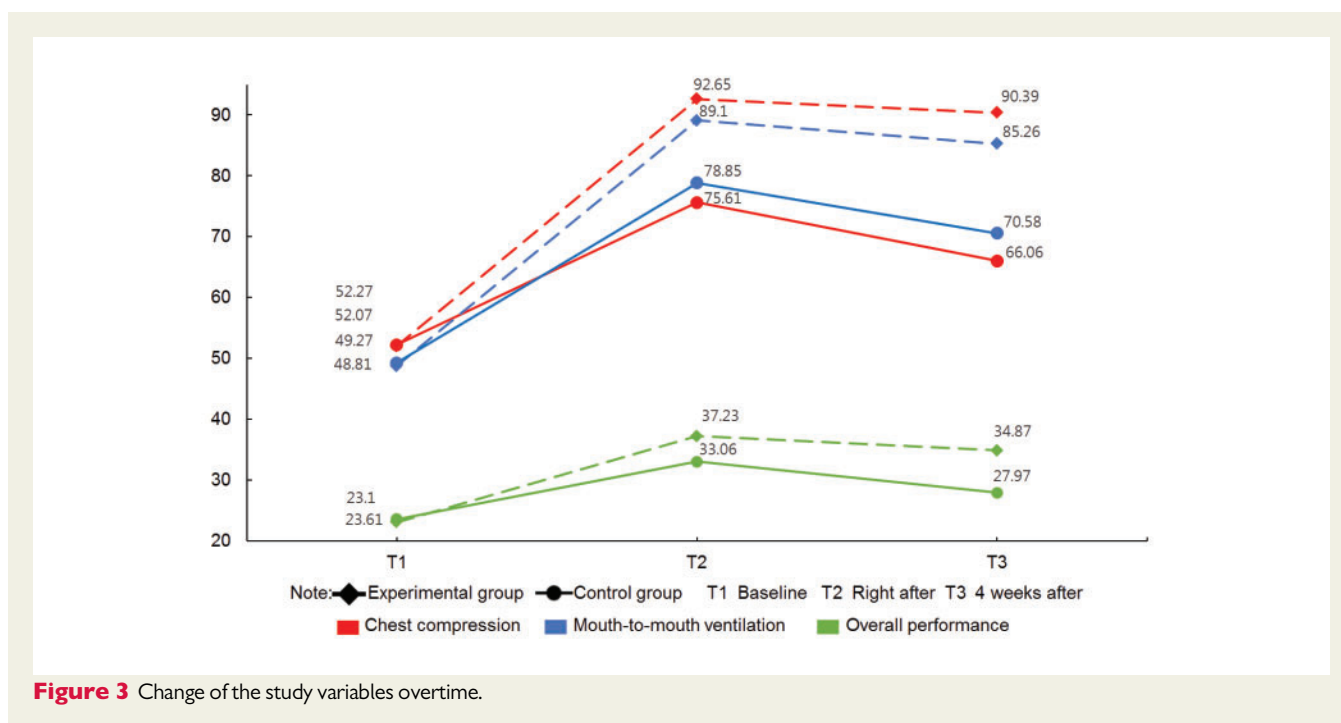
Figure 3 Change of the study variables overtime.

polishing up and maintaining the chest compression skills than mouth-to-mouth ventilation in this study.

Previous studies also found that the CPR training using smart devices such as audiovisual monitoring and CPR meter improved the accuracy of chest compressions significantly.[17,18] In another study developing the smartphone-based feedback algorithm, the smart device could increase the rate of adequate depth of chest compression.[19] With this technology capable of monitoring CPR parameters such as chest compression depth, rate, recoil, hand position, resuscitation volume, and rate, nursing students were able to improve the accuracy of CPR performance.

Overall CPR performance scores of the experimental group significantly increased by 14.13 points at right after training and slightly decreased by 2.36 at 4 weeks later, compared to the control group which increased by 9.45 points and then decreased by 5.09. This enhancement of the CPR performance abilities by the smart technology was consistent with a study of CPR education using a skill-reporting computer monitor, but the computer system was not convenient to check the monitor during the performance.[10] These results suggest that non-contact CPR training with smart technology provide opportunities for nursing students to adjust and improve their detailed skills during CPR performance. Even with face-to-face individual training, it is very difficult for nursing students to recognize their own accuracy levels of CPR performance skills. The feedback as objective measures helped improve adherence to guidelines for CPR accuracy.[20,21] In this study, the visual feedback was given in real-time during CPR performance, so that the performer could evaluate and adjust the accuracy of performance skills for themselves in safe non-contact environments. It also allows students to identify the detailed results of the CPR performance right after the performance facilitating self-directed repeated learning.

Limitations of this study

The study has several limitations. First, it is necessary to examine the sustainable effect of the non-contact CPR training through more follow-up studies longer than 4 weeks, because there are different opinions about the duration of the effects of CPR education.[12,22,23] Second, although the proximity and distance cameras could capture the details of every motion during the performance complementarily, the evaluation by momentary judgement in the face-to-face method during the performance needs to be improved to increase the accuracy of the measurement. Third, to improve the internal validity of the research, it is necessary to include extraneous variables such as critical thinking skills, and self-efficacy in further studies. A study of the accuracy of CPR performance also suggests individual factors such as body mass index, average exercise frequency, and average exercise duration of providers.[24]

Conclusions

The study findings indicate that the non-contact CPR training using smart technology has positive effects on the enhancement and persistence of the CPR performance accuracy and abilities in nursing students. By using the smart technology, nursing students are able to identify and maintain the proper depth, rate, and relaxation in chest compression and the proper level of mouth-to-mouth ventilation, and to achieve the accuracy of CPR performance in safe environments. Based on the non-contact CPR education, they will be able to perform accurate and effective CPR in real situations and to prevent the CPR complications. The non-contact training using smart devices as well as monitoring cameras can be applied as a safe education module for the new normal after COVID-19.

Ethical approval

The study was approved by the institutional review board (IRB) of Kyung Hee University (KHSIRB-16-018NA).

Sample data availability statements

The data underlying this article are available in the article and in its online supplementary material.

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